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BIOLOGY

BY

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PREFACE

In its main treatment this book broadly accords with our "Evolution" and "Sex" already published in this series; and also with its "Introduction to Science," which our Chapters V and VI indeed endeavour to continue.

This small book has thus arisen upon a large plan—that of broadly indicating the main aims and quests of biological thought, and of illustrating their fruitful results. Amid the embarrassing wealth and protean variety of living nature, and the complex webs of relations which are ever being disclosed throughout, we would fain express at once something of the keen and fruitful research-spirit of the biological sciences, and of the rigorous thinking which increasingly inspires them. For the bright and varied pageant of life is being increasingly seen as Bio-drama; and thus with unities to be discerned, as well as manifold and intricate interweavings of plot to be unravelled.

Hence too we seek for keys, admitting us to the ever-accumulating records of the progress of biologists towards understanding more and more of all these aspects of life—

indeed even for such master-key to knowledge as they are finding to be increasingly needed to the treasuries of the other sciences. For these, despite their due distinctiveness, are not only life-created, but life-related, one and all. It is with this outlook that our introduction has been written, and its influence is plain in our treatment of such much-debated problems as mechanism and vitalism, automatism and behaviour.

P. G.
J. A. T.

CONTENTS

BIOLOGY

CHAPTER I

CHARACTERISTICS OF LIFE

THROUGHOUT Nature, Aristotle said, there is always something of the wonderful ("*thaumaston*"); and this is particularly true of the realm of living creatures. But while this is felt by every naturalist, and every biologist too, the definition of the wonder of life—the vital thaumaston—is elusive. What, we ask, is the true inwardness of that particular kind of activity which we call—life? What we see, no doubt, is action and reaction between the creature and its surroundings (organism and environment); but we seek to discover the organism's secret, how it differs from a stone or from a star. We cannot any longer lay stress on the inactivity of the stone, for the inert has disappeared from the scientific universe of discourse. Thus many an atom is comparable to a miniature solar system, with rings of electrons whirling round a central nucleus, like planets round the sun. There is a bustle in the air we breathe: in the not-living as well as in the living, we study what Bacon called "the secret movements of things." Is it then merely that the dance of particles is more intricate in living creatures, that they move to a different tune? Or is there something more?

Here we must pass by the question, to be faced in a later chapter, how we can steer between a metaphysical Scylla and a materialistic Charybdis. Scylla has still many heads, of which "entelechy," "vital force" and "élan vital" are three. Charybdis is still voracious, in reducing to a lowest common denominator everything that she can suck into her whirlpool. Which is to be most avoided—using a metaphysical label, a mere "*x*" to tie up the uniquenesses of life—or caricaturing the organism as an ingenious penny-in-the-slot machine, with an intermittent safety-valve whistle, called mind?

This question must be faced further on; meanwhile our steering must follow a course between the two dangers—a course that will keep the broad features of Nature clearly in view. To vary the metaphor, our picture of the characteristics of living creatures must be a large landscape with clear foreground, yet with distant horizon. This must come first, though later on we may find some satisfaction in Herbert Spencer's often emended definition of life as "the definite combination of heterogeneous changes, both simultaneous and successive, co-ordinated into correspondence with external co-existences and sequences.''

LIFE AS AN ENDURING ACTIVITY.—The plain man's first impression, though generally limited to experience of the higher animals, gets to the heart of the matter; for Life *is* activity. He sees and delights in miniatures of himself, from Reynard the Fox to Brer Rabbit and other homunculi, all of them bustling and hustling creatures that find ways through the difficulties of life, and come out well in the long run. Though the movements of the stars in their courses are sublime, those of the whirligig beetle on the pond belong to a higher order of reality. The beetle commands its course; it is an agent with "a will of its own."

We take a globule of potassium and throw it on the pool, where it rushes about like a thing possessed; but its flare is soon over, and the potassium has disappeared into its soluble hydrate. The movements of the globule were at random and of short duration; those of the whirligig beetle are purposive, and go on for many months. And if it be said that the midges in the air are drawn hither and thither by slight differences in temperature and illumination, pressure and humidity, and that they are transient creatures of a day, the answer is that organisms remain subject to the laws of matter and energy even when they use them for their most definite purposes. In varying degrees they thus become masters of their fate, and self-preservative even in their most strenuous adventures.

No doubt organisms show wear and tear, fatigue and ageing; but their characteristic feature is the ability to wind up their clocks almost as fast as they run down. Whether this ability keeps them going for days or weeks, for months or years, is a detailed adjustment; the essential feature is that they are able, for diverse periods, to balance their accounts of income and expenditure, and even recuperate from their waste by ample repairs. There is good reason for believing that some of the simplest organisms are able to evade *natural* death altogether, thus attaining to what Weismann called " bodily immortality."

Spencer spoke of life as a capacity for " effective response," but is this not shown when the gunpowder reacts to a spark? The difference here is that the explosive destroys itself, while the organism persists. It retains its integrity for prolonged periods in spite of ceaseless change. Life's image is thus the burning bush, flaming away and yet not consumed. Its very activity maintains it, to abide the same.

Plus ça change, plus c'est la même chose. Functioning sustains the organism, though sluggish and disused parts often retrogress. This power of enduring activity is the first and foremost characteristic of life. Later we must think of it in two very different ways: we must see it as the expression of the upbuilding and down-breaking of the living matter (Chapters II and V), and we must also follow it up into its highest expressions, even to intelligent behaviour (Chapter VIII).

GROWTH.—Everyone remembers the saying of Linnæus: Stones grow; Plants grow and live; Animals grow and live and feel. But it requires some modern correction. For we know that plants have senses, and even a tree, as Sir Jagadis Bose has proved, may answer back to a passing cloud. And as to the growth of "stones," the increase in the size of a crystal is only remotely comparable to the growth of a sapling or of a young bird. When a small piece of crystal is placed in a somewhat concentrated solution of the same substance, or of another substance with an identical mode of crystal formation, it increases in size in an orderly and beautiful way. The molecules in the solution are attracted to the surfaces of the little piece of crystal, and, uniting into little groups or "crystal-units," are added to the already existing edifice. But the living creature absorbs its food, transforms it, and uses it to increase its body from within. This is very different from crystal-accretion or the enlargement of a rolled snowball. Moreover, the living creature, whether plant or animal, obtains its growth-material from food substances which are, in varying degrees, very different from what they become. Thus the green plant utilises air, water, and salts;

and the foal grows at the expense of the grass.

The fundamental condition of growth is that income should exceed expenditure; there must be a surplus of nutritive material beyond what is needed to provide energy for every-day work and to effect the necessary repairs. It is not too much to say that the whole economy of Nature depends on the fact that green leaves are able to use some of the orange-yellow rays of the sunlight that suffuses them, to build up complex organic compounds out of carbon dioxide from the air and water with its salts from the soil. They live so far below their income that they have an abundant surplus for their offspring and stores on which the whole animal world directly or indirectly depends for sustenance.

Familiarity dulls our eyes to the marvel of growth—the covering of the brown earth with verdure; the desert blossoming as the rose; the bamboo rising a foot in a day; the Big Tree increasing in bulk for two thousand years; the coral-polyps forming a breakwater a thousand miles long; the Arctic jellyfish (*Cyanea arctica*) becoming bigger and bigger till the disc is over seven feet in diameter and the tentacles trail in the waves for over a hundred feet. Again, many an animal egg-cell forms a body that weighs a billion times as much as its beginning; and this is far exceeded in the growing up of giants—like a Blue Whale, eighty-five feet in length, or an Atlantosaurus with a thigh-bone as high as a tall man.

Giants there are and have been in many groups of animals; but they tend to be short-lived, as animal historians count short; and a more important feature of growth is its usually strict regulatedness. In subtle ways—because of the proportions that must be sustained between volume and surface, because of internal chemical messengers that come from controlling glands and pass throughout the body, and because of the strange balancing influence that one part of the body exerts on another, growth is regulated. The majority of animals have a definite limit of growth—the optimum physiological size for their particular constitution; and the reaching of that limit is the signal for reproduction.

Reproduction.—The corollary of growth is reproduction. This essentially means separating off portions or buds, spores or germ-cells, which start a new generation. As Haeckel said long ago, reproduction is discontinuous growth; the simpler forms of reproduction are preceded by conditions of physiological instability, which tend towards a separation of surplus material.

Instances of the prolific reproductivity of organisms are familiar. In one day the multiplication of a bacterium may result in a number with thirty figures. Were there an annual plant with only two seeds, it could be represented by over a million in the twenty-first year. But a common British weed (*Sisymbrium officinale*) has often three-quarters of a million of seeds, so that in three years it could cover the whole land-surface of the globe. Huxley calculated that if the descendants of a single green-fly all survived and multiplied, they would, at the end of the first summer, weigh down the population of China. A codfish is said to have two million eggs, a conger eel ten millions, an oyster twenty millions, and Mortensen estimates the annual productivity of the starfish Luidia at two hundred millions. As this starfish is not common, we are reminded that fecundity is not to be confused with actual increase of population; yet the large fact stands clear, that organisms have an enormous capacity for increasing their living material, and for liberating part of it in the form of new individuals. They are continually transforming food into life.

A vortex-ring, say of cigarette smoke, may divide into two; a molecule may disintegrate into simpler molecules. Much as radium disintegrates, so protactinium may beget actinium, which begets thorium, which begets lead. A nebula may resolve itself into a double-star;—all these have, in their way, certain analogies to reproduction, though of course without its organic distinctiveness. Yet far be it from us to suggest that they can shed no light, were it even on the butterfly and its caterpillars, the salmon and its alevins, the eels and their elvers, the frog and its tadpoles, the swan and her cygnets, the mare and her foal! For we cannot think of living creatures as without solidarity with the earth—wonderful "emergents" though they be. They are not of the order of Melchisedec, King of Salem, "without father, without mother, without beginnings of days." Life was a new synthesis; yet it must have had an inorganic ladder on which it climbed.

When all is said, however, reproduction remains as an outstanding characteristic of organisms as contrasted with non-living things; and to be regarded not as a process by itself, but as following growth in well-marked rhythm. The see-saw between feeding and breeding, leafing and flowering, nutrition and reproduction, is fundamental in life.

Development.—In his discussions of the characteristics of living creatures, Huxley was wont to lay emphasis on what he called "cyclical development." Within the embryo-sac, within the ovule, within the ovary of the flower, a miniature plant is formed by the division and re-division of the fertilised egg-cell. The ovule becomes a seed; and this, when sown, a seedling. By insensible steps there is fashioned a large and varied fabric, of root and stem, leaves and flowers. But sooner or later, after this is finished, the grass begins to wither and the flower thereof to fade. In an annual plant, there is soon nothing left but the seeds, which begin the cycle anew. It is, Huxley said, "a Sisyphean process, in the course of which the living and growing plant passes from the relative simplicity and latent potentiality of the seed to the full epiphany of a highly differentiated type, thence to fall back to simplicity and potentiality again."

So is it also among animals. In some way, of which we can form only the vaguest image, the germ-cell (whether ovum or sperm) contains the specific inheritance, the long result of time. Invisible "factors," possibly ferment-like in their potency, are lying ready to be activated, and this is effected in fertilisation. By the division and re-division of the fertilised egg-cell, an embryo is built up. Division of labour sets in among its units, and the structural side of this is differentiation. Out of the apparently simple comes the obviously complex; some cells become nervous, others muscular, others glandular, others skeletal; and so the marvellous process continues. Sometimes the embryo develops steadily and directly into the likeness of its kind, as in birds and mammals, with only traces of circuitousness—tell-tale evidences of the lien the past continues to hold upon the present. Thus the embryos of birds and mammals form gill-clefts which have no respiratory significance, but appear as relics of a long-lost aquatic ancestry. The first cleft gives origin to the Eustachian tube, from the ear to the back of the mouth; the second has to do with the formation of the thymus gland; but the others quickly disappear, leaving no trace at all. Here is one of the large facts of development, that the individual shows, in varying degree, evidence that he is "climbing up his own genealogical tree." The past lives on in the present; and, especially in the development of organs, there is some considerable recapitulation of great steps in the history of the race, compressed though it be.

In many cases, however, development is not direct, but takes a zigzag course, through the interpolation of larval stages, as familiarly in caterpillars and in tadpoles. These are special and later adaptations to meet difficult circumstances; indeed to overcome them, and with marked success: thus the caterpillar is a voraciously feeding and rapidly growing creature, accumulating stores of energy, which (notwithstanding partial expenditure in metamorphosis) aid—or even fully enable—the butterfly to lead its joyous life, up to its fatal climax with reproduction. Again, many of the animals of the shore—a hard, yet evolutionary, school of life—have delicate larvæ, *e.g.* those of crabs and sea-urchins, which spend their youth in the much easier conditions of the open sea. They could hardly survive for an hour in the rough-and-tumble life of the sea-shore.

Development must not be thought of as restricted to juvenile stages. It is the whole individual progress of the organism. Through more or less critical phases of adolescence there is an advance to adult strength, and in many types the mature period, of maximum mastery and freedom, is of long duration. But whether the creature's life be counted in days or in months, years or centuries, there is for most an ascending and a descending curve (Chapter VII), from the *vita minima* of the liberated egg-cell (which often dies in a few hours if it be not fertilised) to the second *vita minima* of senescence, or to the yet more frequent anti-climax of violent death.

So far then we have noted three outstanding characteristics of life—growth, reproduction, and development—which must be linked up with the fundamental vital activity with which we started. Growth is the expression of a preponderance of constructive processes; reproduction in its simple forms is the outcome of a physiological instability that tends to set in at the limit of growth. And when we also consider cases of regeneration—in which an organism replaces a lost part, or a separated-off part grows into a new organism—we come to see development—even of the egg-cell—as a continuance of the fundamental process of repairing the results of wear and tear.

Variability.—The child playing with a kaleidoscope, and wondering at the seemingly endless succession of different patterns, is having an early lesson in variability. Later may come observation of the variety of snow-crystals. And while crystallographers enumerate only thirty-two main forms in the mineral or chemical world, yet when Sir

William Bragg looks into their interior, mysteriously lighted up with X-rays, he finds no fewer than 230 different modes of arrangement within the crystal-units. Or, again, there is the epoch-making modern discovery that the transmutation of elements was not a dream. Thus uranium passes into radium, and perhaps mercury can be turned into gold. One also hears of things being the same and yet different, thus radium-lead, thorium-lead, and actinium-lead are all lead, yet different from one another, and even from the lead we all know. Here then are cases of inorganic variability; but in suggestiveness these are far surpassed by the many organic series created by organic chemistry, *e.g.* in the unending succession of new dyes, perfumes, or explosives. The organism is the supreme though unconscious creative chemist: yet we can find a better metaphor in the artist, who strews his studio floor with his sketches; or in the musician, who improvises as he plays.

Many familiar species, here the goose or there the bracken, now show little or no appreciable variation, but present well-nigh complete hereditary resemblance from generation to generation. More striking in their permanence are the Cambrian Lingula, the Silurian Nautilus, the Triassic mud-fish Ceratodus, which have remained much the same for uncounted ages,—types with a well-equilibrated constitution that have been able to resist not only Time's mordant tooth, but, in some cases, considerable changes in their environment.

But, while these saving clauses are necessary, the larger fact is, that the keener the scrutiny of life, the more striking is the disclosure of variability. There are often great differences in a single family, and greater differences between the offspring and their parents. Man's own variability is very striking; much above the average in Nature. There are three reasons for this: his complex individuality to start with, with a multitude of differences; his intricate admixture of races; and the protection and tolerance secured by society, in time even for variants that would not otherwise survive. No doubt, too, our impression of man's variability is somewhat exaggerated by our familiarity with our own kind, so that we have a quick eye for even slight changes.

What impressions of variability we get at a "show"—whether of dogs or pigeons, roses or pansies! Here we have, as it were, the fountain of life rising high in the air—blown into strange forms by the breeze, yet modulated, to its own ceaseless waxings and wanings, by varying pressures from its source. The different forms described by Jordan in one of the commonest of small crucifers (*Draba verna*) are above 200; and these are no longer fluctuating but breeding true. Again, Lotsy speaks of the bewildering diversity exhibited by a series of about 200 specimens of the Common Buzzard (*Buteo*

buteo!) in the Leiden Museum, "hardly two of which are alike." It is difficult to see much difference between one reeve and another, but it is as difficult to find two ruffs that look alike. One may easily collect fifty guillemot eggs without one of them repeating the identical colour-pattern. Whenever one settles down to work at species, one is confronted with the difficulty that so many of them are in flux.

Enregistration.—A bar of iron is never quite the same after it has been severely jarred, and the "fatigue of metals" is one of the serious risks of engineering. A violin changes in character according to the treatment it receives, and they say that some jewels are the better for a rest now and again!

But these can be little more than first analogies of the distinctive power that living creatures have of enregistering the results of their experience, of establishing internal rhythms, of forming habits; and of the more mysterious power of adding interest to the hereditary capital. In the individual lifetime the organism is modified by what it does, enregistering the results of its own reactions: in the life of the race there is also an entailment, though it is still unsettled whether this ever amounts to the transmission of acquired characters in any direct way. But keeping to what is certain, we know (1) that the inheritance of every race of organisms implies a summation and continual re-organisation of ancestral gains; and (2) that the way the parts of an organism react to stimuli is determined not only by the innate constitution, but by the accumulated experience of the parts in the individual life-time. As W. K. Clifford said, "It is the peculiarity of living things not merely that they change under the influence of surrounding circumstances, but that any change which takes place in them is not lost, but retained; and, as it were, built into the organism, to serve as the foundation for future action." As Bergson puts it—"Its past, in its entirety, is prolonged into its present, and abides there, actual and acting." This is what some biologists mean by calling the organism "an historic being."

Behaviour.—We began our survey with the activity of the living creature, and with the endurance of its individuality in spite of ceaseless change. But behaviour means something more—a chain of acts leading to an effective result, and the linking up of this chain is the organism's most distinctive characteristic. A good illustration—for the instinctive level—is the behaviour of the Yucca Moth. When the large yellow bells of the yucca plant open, one each evening, the silvery moth, just emerged from her chrysalis, sets forth to visit them. She behaves as to the manner born. From the anthers of one flower she collects pollen, kneading it into a ball, which she holds beneath her chin. She flies to another flower, pierces the pistil with her ovipositor, lays her eggs among the ovules, and then pushes the fertilising pollen-pellet into the funnel-shaped opening of the stigma. Without the pollen thus brought by this moth to the pistil, the ovules would not develop, as no other visitors seem to be effective. The larvæ of the moth eat a number of the developing ovules, but not more than about half of them. Were it otherwise, the linkage would have broken long ago. The moth only does this once in her life, but it is none the less *behaviour*—a sequence of adaptive actions.

This example—one must here suffice—is, of course, far below the intelligent behaviour of apes and monkeys, dogs and horses, yet as far above the simple tentatives of many of the lower animals. But even among the relatively simple unicellulars, there are good cases of behaviour. Thus Jennings describes an Amœba on the hunt. It followed a small one, caught it, engulfed it, yet lost it. But again there was a chase, and again capture and ingestion. Then the small Amœba got away once more! The story ends here; but was not all this clearly something of behaviour? Did not each Amœba show in rudiment what the zoologist himself might have done?

Growth, reproduction, and development are a connected triad of characteristics; for the first leads on to the second, as that to the third. Similarly, when we think of the organism as creative, acquisitive, and masterful, we may bring in a second and parallel triad—

variability, enregistration, and effective behaviour. Yet the summation of all this does not fully give us the organismal life we know. What does our picture of life still lack of completeness for its place as the very frontispiece of our Biology?

Insurgence.—What we have to add is first of all some appreciation of life's insurgence; meaning by that more than we can readily say. We mean, for instance, that there are multitudes of different forms, each affirmatively specific—itself and no other. Thus there are 250,000 different species of backboneless animals, named and known; and the census is not nearly complete. Insurgent also is Life, in the way in which, with its stream in flood, its offspring spread themselves over the earth, leaving no corner untenanted, or at least no niche of opportunity untried. On the heights of the mountains above the snow-line there are still a fauna and a flora; in the cold, dark, plantless, inhospitable world of the Deep Sea a multitude of animals are at home, even to abysses in which Mount Everest would disappear. Fresh-water life has re-adapted itself even to the bitterest brine, as in the Great Salt Lake of Utah, worse than the Dead Sea itself. Life searches, even blindly, into caverns; it inures itself to hot springs, yet survives under ten feet of ice on the Antarctic shore. Where is life not to be found? Even coal-mines and water-pipes have their fauna and flora! Such facts are no mere curiosities, but expressions of the insurgence that is characteristic to the picture of life.

We mean also by insurgence what Goethe said—that animals are always attempting the impossible and achieving it! There is an adventurousness in their exploits; as with the wingless spider making aerial journeys on its slender gossamer. So with the Robber Crabs climbing the palms for coco-nuts; or again with the delicately-built storm-petrels spending their whole life, save brooding time, amid the restlessness of the open ocean. So we might continue, indeed for many pages, since these examples are but signal instances of a general quality of life, its indomitable facing of difficulties, even to their conquest. The migratory birds have long anticipated man, both in annihilating distance and in circumventing the seasons—"they know no winter in their year." One of the delights of Natural History is this continual disclosure of life's mastery over untoward circumstances and difficult materials too. We see this mastery in the wasp's paper nest, made of wood-pulp from the trees, and still better as we may watch her tearing off long strips from our garden paling. The many-storeyed termitary is built of salivated earth, to a height of, it may be, ten feet; and other termites carry darkness with them in long tunnels, up the trunks and along the branches of trees. See too the swinging nests woven by the Indian weaver-birds, pass to the Canadian beavers building the huge and enduring dams which may become future meadows, or return to our own garden, with its unsurpassed architecture of the honeycomb.

We must include too the thousand and one adjustments of structure and function that arise to meet peculiar difficulties,—thus the insect-catching of the sundew, which ekes out its scanty nutrition on the moor; or the climbing and twining up-swing of honeysuckle, hop, or vine. See too the flatfish's ready assumption and even adjustment of its cloak of invisibility; or hear the rattlesnake's ominous note, more feared than a common snake's hiss. The cuttlefish throws dust in the shark's eyes; the fox plays 'possum; and the gay butterfly may vanish, transmuted into a withering leaf.

Never yet done full justice to, even by artist or poet, is the quality of beauty. For this is manifest, in varying degree, in all independent-living organisms, above all when seen in their natural surroundings. If there be exceptions, they prove the rule; for the only creatures we cannot hail as things of beauty, and remember as joys for ever, are certain half-finished embryos, certain diseased or crippled organisms (very rare in wild nature), certain parasitised victims or thorough-going parasites themselves. Another exception must, alas, be made for those over-domesticated animals and over-cultivated plants that bear the mark of man's heavy hand. Selected towards his ends too exclusively utilitarian, such as fattening in pigs, or gigantism of bud in cabbage, races are established which have lost much, or most, of their native beauty. It is only because they are under man's protection that they survive at all. But barring such readily intelligible exceptions, it is the rule of life to be beautiful. Yet there is obvious beauty, like that of the peacock's tail, and beauty less obvious, as in the grotesque chamæleon, or the whimsical-looking bat. Organisms are like works of art, of all various schools and levels, and with some excelling others in their significant expression of life and feeling.

Picture the plumed sea-pens gently swaying themselves on the calm bed of the ocean, like wind-swept daffodils by the lake. The common sun-star glows like a tiara of rubies. The red-admiral butterfly flutters over the meadow; the argonaut sails the open sea in its delicately moulded shell, the most exquisite of Nature's cradles. Picture again the proud attitudes and tumblings, yet drollest twistings, of the sea-horses among the tangle. The tree-toad is for Walt Whitman "a masterpiece for the highest." Ruskin's "rivulet of smooth silver" we call a snake, and have to admire in spite of fears deeper than human. The kingfisher darts upstream like an arrow made of rainbow. See the herd of deer on the hill-edge, with their leader's antlers silhouetted against the sky. And so on and on, in embarrassment of Beauty's riches,—beauty crowding on us, even at our doors, in protean wealth of form and colour, of pose and movement.

Disagreeable associations—such as having been stung by a jellyfish or by a nettle, or child-repulsion as from "the loathed toad"—hinder appreciation of what an artist may lovingly delineate. So conversely; even pleasant associations cannot fully account for our æsthetic thrill. Strange animals from the Deep Sea, creatures that human eye has never before seen, are hailed at once as exquisitely beautiful, though we cannot link them to previous joys in our experience. In any case, experiments on children and other unsophisticated people show that certain shapes, colour-patterns, and movements are much preferred to others.

The quality of beauty in living creatures is surely also an expression of harmonious health and orderly active life. Thus we take "looks" as their index, for are we not always hearing in everyday speech "She (or he) was (or was not) looking very well"? Throughout Nature, more than in tolerant mankind, we recognise that elements discordant with beauty have been eliminated.

It should be remembered, also, that a beauty-feast may be spread on a microscope slide; and that many a fascinating pattern is interior, and out of all sight, as witness the zoned structure of a tree-stem, or the like in miniature in the build of a sea-urchin's spine.

Some animals seem to take a delight in the homes they build without hands; for one must be a hard-shelled behaviourist to believe that the bower-birds, in collecting the beautiful leaves and flowers and shells that adorn their courting-runs, are automatically reacting to aphrodisiacs.

We must not linger longer over these bright aspects of life; but our picture of life's characteristics would be incomplete without such recognitions of the practical universality of beauty. This characteristic is no more to be ignored than is metabolism itself; the more since also internal. The poet's line—" her temple face was chiselled from within " —has wide application throughout Nature.

This brings us to another characteristic. No one doubts that mammals and birds have at the very least some analogues of our subjective life. Even the behaviourists recognise " mind," though they maintain that for practical purposes it does not count. But as in the life of a child we cannot say, " Lo here," and " Lo there," when mind is dawning, so, through animate nature, who can yet say at what levels mind is still wholly slumbering; or exactly how far in different forms it may be awake, awakening, or only stirring in its sleep? The fundamental evolutionary concept of continuity suggests that there must be throughout Nature something of that psychic light which even in man is still but approaching the perfect day. Whether we are to think of an *anima animans* playing on the body as musician on his violin, each thrilling to each; or of a double-aspect reality, body-Mind and Mind-body, bio-Psychosis and Psycho-biosis, is a further question.

At any rate, we cannot fear to include in our picture of living things their promise and potency—in higher reaches, their epiphany—of "Mind." But this is not merely, nor even mainly, in distinct intellectual expression,—that is but a late (and still imperfect) development,—but in the well-springs of feeling and in the bent and discharging bow of purposive endeavour. Processes cognitive, emotive, and conative—the customary presentment of mind—are not their evolutionary beginnings vibrating in ovum and embryo—and thus from Protozoa to Metazoa in their ascent? Are they not faintly sounding in coral and sea-lily, increasing in more active animals, coming even to music in the birds? Mind is thus always in its beginnings old, yet with developments ever new; for it is not Man alone who can take three sounds and make of them "not a fourth sound, but a star"!

All these several characteristics of life have now to be seen united, in Life itself. Is this unity now in life's forms as we know them? Or is there not a greater and grander view including all life and all its changes, past, present, and even possible? That is Evolution.

Just as above we have returned to the consideration of Behaviour, and looked at it afresh in a frankly psychological mood, so we must re-envisage Variability. For what we saw of it as flux, and as characteristic of organisms in their generations, was in too cold a light. It is not merely that the new diverges from the old, and often takes its place: there has been, on the whole, an advancement of life. As epoch has succeeded epoch for inconceivable years, life has been slowly creeping—or swiftly leaping—upwards, and towards greater fullness and freedom. In spite of occasional retrogressions or blind alleys, in spite of the extinction of fine types like sea-scorpions, great races like flying-dragons, there has been a generally progressive trend in evolution. There has been in this a growing emancipation of the Psyche, and an emergence of lives which cannot but seem to us increasingly satisfying—life-justifying—in themselves. We see in Nature at its higher ranges brave lovers, devoted parents, affectionate children, loyal kin; and even from the lowest we find creatures whose work is art, whose every movement is beauty. We do not shut our eyes to the battle that is so often to the strong, yet we see, and just as definitely, the homes of the loving. We cannot ignore the rewards that come to the self-assertive nor the success that is won by the well-girt loin; yet there are even greater rewards and higher successes for the self-subordinating and altruistic types of life. For, after all, it is thus that the birds and the mammals have come to crown the genealogical tree of Life.

After all due analysis, each organism and type has to be viewed in its place, as the flower upon its branch of Life's protean tree; and as at once in itself an evolving system, yet part of a far greater. And through all these varied ranges of blossomings, do we not see many urges, strong and lasting, towards what Man at his best has ever held to be best—the Beautiful, the True, the Good?

In summary, then, the deepest as well as the completest characteristic of Life is its potency, its achievement, and its unending promise of Evolution.

CHAPTER II

BIOLOGY AND ITS LITERATURE

Sub-Sciences of Biology.—What are these? First comes the morphological group, of Anatomy and Classification (Taxonomy), of Paleontology (say rather Paleontography, as its busy and learned society does), and of Embryology (or rather Embryography, since here again, until we are more than microscopists, we can but observe and describe more than we understand).

These are the four morphological sub-sciences; what are the four (corresponding) physiological ones? First comes "Physiology"—in its ordinary sense of the functioning of individual bodies. Yet this implies touch with Ecology—*i.e.* the old "Natural History," the "Larger Physiology" of Wallace, the "Higher Physiology" of Semper, and identical with the "Bionomics" of Ray Lankester. Bionomics is a good name, since using the other half of economics—but it fails to justify adoption, since Haeckel's name was first in the field, and is indeed preferable, since linking up with the ways of man.

Here indeed in this matter of naming, so essential for clearness, a further word of criticism is necessary. The general name of Biology, though devised for the whole subject, and generally thus used, has sometimes been mis-applied, even by otherwise careful writers, to Ecology alone, and with confusion accordingly. "Ecology" has its own field, but "Biology" includes all the sub-sciences together.

Finally have arisen the evolutionary sub-sciences of Ontogeny and Phylogeny, those which seek rationally, *i.e.* dynamically, to interpret the development of the individual and of the race respectively. These, since obviously interactive, are sometimes taken together, and named Ætiology; but for practical purposes the term Evolution remains in customary use.

But the reader, if of due scientific scepticism, as he should be, may here ask—How do you know that biology has just these eight divisions; no more and no less? To this there are several answers; so first the simplest.

Why eight sub-sciences? This is a rational enquiry—to be met fully later; but here first by simple verification, one by one in nature-study experience; while no others are to be found.

But it will at once be asked—What then of ornithology, ichthyology, entomology—what of bacteriology, fungology, orchidology, and so on? Are not each and all of these sub-sciences of biology?—indeed increasing in indefinite numbers, and with corresponding variety of details, and of problems accordingly?

This apparent difficulty is, however, readily cleared up. The preceding arise but as fields of Taxonomy; and they apply to particular groups in their classifications; as indeed do Botany and Zoology themselves. It is thus readily evident that whether our particular interests or duties specialise us on birds or fishes, on insects or on flowers, or extend even as far as general Zoology or Botany, our very same eight sub-sciences arise, as we ask questions about any or all of these types or groups. Thus: How are each and all of these —bees or blossoms—constructed? (Anatomy.) How shall we classify them, in detail and in relation to kindred forms? (Taxonomy.) How do they develop? (Embryography.) What do we find of them in the past? (Paleontography.)

And similarly for the other four sub-sciences. For beetle, bird, fungus, flowering plant: What is its individual and inner functioning? (Physiology.) What are its larger, more general, life-relations, in its natural environment, to others of its kind, and to other forms of plant and animal life? (Ecology.) And, finally, what rational account of its origins can we spell out? (Evolution.) And this not only as regards its individual process of development (Ontogeny), but also of its family tree, its general line of descent, and even the rationale of this particular line of origin? (Phylogeny.)

There then are our eight questioning and researching sub-sciences, all equally applicable —in principle, whatever be the practical difficulties—to all forms of life; and indeed, may we not say? as bow to violin. We see thus a clearing up of the two-fold aspect of Biology (as indeed of other sciences, physical or social). For we begin with observation in its concreteness and variety; yet this calls us to deeper intellectual quests; first that of orderly (classified) presentment, and next that of interpretation as far as may be. In summary, then, our essential sub-sciences of biology constitute an eightfold questionnaire, through which all forms of life have to be put, with the aim, even the growing result, of knowing more and more of Life. We ask not only of life in the present, but of life in the past, and why not—indeed above all—what of its possibilities as well? This evolutionary insight is indeed our highest goal: for biology —like every other science, more or less— follows the great rule best summed up in a terse phrase of Comte's well-nigh a century ago, but in practice since the early days of science, as witness, astronomy, and medicine, for choice—"*Savoir pour prévoir, prévoir pour pourvoir.*" Know in order to foresee, and foresee in order to provide. Here is how knowledge comes to application and use, as biology to medicine, agriculture, and more— in a word, towards Biotechnics.

THE LITERATURE OF BIOLOGY.—Yet we have not fully justified our eightfold analysis of Biology; nor faced its immense literature. Let us therefore try a fresh line of elucidation, indeed that by which this arose for us many years ago [article "Biology," *Chambers' Encyclopedia*].

The literature of every science is so vast as utterly to exceed the reading powers of its most eager cultivators: thus in botany before the war, between its journals (said to be 400 or thereby) and its many books, a current estimate of what the ideally comprehensive botanist ought to read was about 300,000 pages annually! In zoology probably no less, and in other sciences, especially chemistry, far more. Yet we all readily get into trouble when we overlook, as is so easy to do, another's priority of publication: and thus reclamations appear, often stinging ones; and sometimes positive controversies, even bitter. When the difficulty between Leibnitz and Newton, and still more among their followers, over their respective contributions to the calculus has taken till recent times reasonably to settle, how much more are there such possibilities in our days, and opening ones, with immeasurably more publications, and in an ever-increasing number of languages? Then too, apart from controversies, think of the loss to science, and even to agriculture and life, from overlooking discoveries: witness, and as only one example, that of the (rather out-of-the-way) publication of Mendel's great experimental work, which, instead of helping even Darwin, and doubtless yet more his whole subsequent generation, remained unknown until the re-discovery of his principle in 1900. Biologists and, above all, breeders, are only nowadays properly appreciating and utilising his amazing pioneering, but this too late to have encouraged him to its fertile continuance with his fuller preparation, and thence their own far earlier and better start.

Hence, then, and in many ways, the need of laborious and copious bibliographies: thus, even a generation ago, the "Mollusca" section of the "Challenger" Expedition's Report gave several thousand references; and twice that number would doubtless in our day be insufficient for completeness.

To meet such difficulties, even the best of general librarians are not enough. So each science has to take up its own work. Bibliographies thus arise, becoming increasingly comprehensive and co-operative, *e.g.* the annual *Zoological Record* or the invaluable *Botanisches Jahresbericht*. Quarterlies, monthlies, even weeklies, increasingly strive to meet the urgent needs of their specialist readers. But even these do not suffice; hence largely the more comprehensive endeavour of the International Association of Academies since the beginning of the century; yet even this was largely breaking down under its own weight and complexity, before the War, and has been inhibited since. Even the magnificent endeavour of Otlet and La Fontaine's Institut de Bibliographie Universelle has had all these difficulties and more:

so now the League of Nations—through its Committee for International Intellectual Relations, with M. Bergson presiding, and keen minds, even Einstein's, to help him—is again facing this enormous task. One of these able members—Dr. Hagberg Wright of the excellent London Library—is working up the plan of forming Committees for each language, whose periodic duty it will be to report its salient contributions to Geneva. So far well, especially for literature, history, etc.; but how in science can we make sure —at any rate surer—not still too readily to miss our coming Mendels? *Quis custodiet custodes ?*

Here then is one of our great modern cases of " Psyche's Task " : and that indeed more difficult than hers, since even our admirably ant-like bibliographic industry and patience is just what has been and is failing to cope with the amount of material, the multitudinous grains, and of varied knowledge, to be arranged.

Who then is sufficient for these things? The ablest individuals, their best co-operations, cannot wholly be trusted; nor should even they fully trust themselves : for what senior men or group, in any subject or field, and however competently acquainted with their predecessors and with each other, have ever been able adequately to appreciate their emerging successors, especially when breaking paths beyond theirs? Whoever will look carefully, not only into the history of the sciences, but even their present state, will have to think twice before he throws stones at the old theologians. Yet perpetual innovation is the very life and movement of science.

Here the librarians cannot fully help us, for all their receptiveness; thus Mendel's papers were shelved. They reply—Use our classified catalogues, and thus you find everything. But can scientific workers adopt any one of these classifications? Not satisfactorily, and for two sufficient reasons. First these still differ, and from library to library; and though, for salient instance, Dewey's well-known decimal classification has had wide adoption—witness its utilisation even for Otlet's more than 12 million cards —other librarians are replacing it; nor has it been adopted either by the Academies or at Geneva. The second reason is yet more serious. For the library, as restaurant and even feasting-hall of knowledge, the authors are but the cooks, and the librarians (with all respect) are but the waiters. We, the readers, are essentially at the mercy of the cooks, and our criticism of each of their finished works is too late to affect it, at any rate in that edition. But the best waiters are those who serve us most promptly; and other things equal, this depends on the excellence of their pantry arrangements; into which, however, as behind the scenes, it is none of our business to enquire. That in the Bibliothèque Nationale one may wait forty-five minutes for one's book, in the British Museum half-an-hour, but in the Library of Congress ten minutes, is enough for you or me, as an impatient reader, thereafter to swear by the classification of this last, on whatever principle it be, as best for our immediate purpose.

Yet now let us briefly enquire into these classifications. The working convenience of the Dewey system depends on its handy grouping of everything in the pantry into tens, with minor subdivisions into tens, again as often as need be. But what has this convenient practical device to do with the rational classifications of each and every science? Thus, for instance, we can only find eight biological sub-sciences, not ten; and Dewey's technique does not, obviously cannot, exactly work with or in these. And similarly through all fields of knowledge. Nor indeed can we adjust a science to other cataloguing systems either.

True, most explain their various rational bases as in fair accordance with the main interests of their reading public, though these, to do Dewey justice, determined his main groupings too. Furthermore they have done their best with various groupings of knowledge, those, for instance, of university faculties, and often as carried further in classifications of the sciences, not forgetting Bacon's, or later systems, Comte's, Spencer's, etc. But their results, however convenient, cannot satisfy each other.

In short, despite all increase of libraries and bibliographies, we are still overwhelmed;

and things grow worse, since "of making books there is no end, and much study is a weariness to the flesh."

Biology to the Rescue.—How can this be? First, because "all knowing is classifying"; and second, because Biology, in the vast taxonomy of its plants and animals, is the classificatory science par excellence. Just as mathematics is the master-science for all manner of counting and measuring, and chemistry for weighing everything, so is taxonomy the discipline for classifying; and again no matter what. Thus its fundamental classic, Linnæus's *System of Nature*, though apparently limited to classifying animals, plants and minerals, is really and deeply far more. It is nothing short of the world-masterpiece of applied logic, and thus the outstanding exemplar of order in all things. Understand first his herbarium, now the main treasure of the Linnean Society, and too precious for popular use; but any later one will do. Look over its buttercups, for instance, *i.e.* his genus *Ranunculus*. Here is a specimen of each species, and of each variety even; each neatly fixed on one side of its large sheet of paper, and duly labelled in the corner with particulars of its locality, etc. The two names, the generic and the specific, became henceforth established, whatever previous authors may have called them. As we find and name new species, many since Linnæus' day, the new specific name bears also its discoverer's initial for clearer identification, leaving *L.* for Linnæus, to record his earlier known forms.

Thus our herbarium is in principle a card-catalogue, indeed is ancestral to this, and next to loose-leaf ledgers and the like, though its user be M. Jourdain himself. It answers exactly to a subject-catalogue, and, like it, is capable of extension indefinitely; thus including the whole plant-world in one case, the whole book-world in the other. But the first is the better standardised. The librarian may indeed keep any rational group of books together, say his collection of plant-floras; and for practical purposes he too gives each a letter and a number, say to Hooker's L. 452, and to the next one L. 453. Here then is an analogue of Linné's generic and specific name, but only applied to define the shelf and the exact position of the book in that library. But if Hooker's Flora were L. 452 throughout all libraries, and also code-indication for the whole book-trade too, then this would be up to the Linnean standard of orderliness.

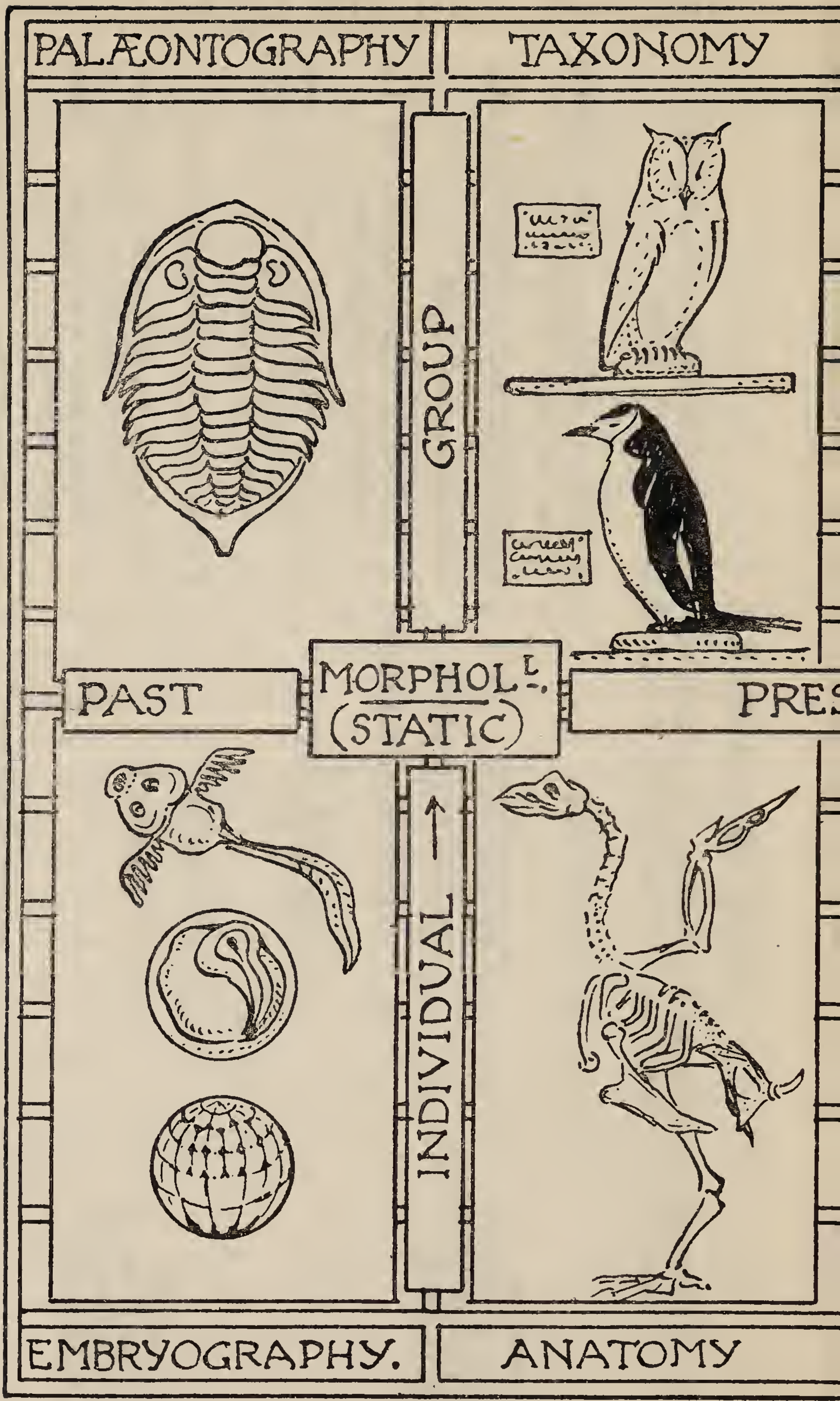
But Linnæus' classification, natural in its species, and mostly even genera, was but artificial in its larger groupings of genera into orders, and so needed change? Certainly so; and though his disciples long adhered to this first broad and convenient working outline, and mostly resisted the more nearly "Natural System" of Robert Brown and De Candolle until this survived them, there are grounds for maintaining that Linné himself knew his artificial system, in its larger outline, to be but a preliminary scaffolding for the Natural system, already partly foreseen, even beginning, in his day. Plant classifications, in their larger groupings, are still far from perfect, and thus in progress and debate; and the re-arrangement of botanic gardens, to keep pace with these, is obviously even harder to effect than that of great libraries: but, thanks to their more manageable herbaria, the botanists are still leading the way. So where classified collections, botanical, zoological and mineral, furnish the only subjects of a special library, its cataloguers and librarians have no too great difficulty in keeping abreast of these three museums and curators, however active collectors these may be, even advancing classifiers as well.

But our library difficulties, since next for biology in all its departments, are far greater, and thus still too much unsolved. But why not take a second step, and from the biological side—that is, primarily, for the most rational possible grasping of the whole literature of our various sub-sciences—since this will be best for readers, however secondarily for the working convenience of librarians? After all, speedy delivery is not the main thing for our intellectual feast-hall: what we want is the full dietary, and in due succession of courses, best suited to our digestion and desire. And the former first, when we have our young families with us—in this case our students—while even for an honoured guest—in this case the gentle reader—we have to consider standard

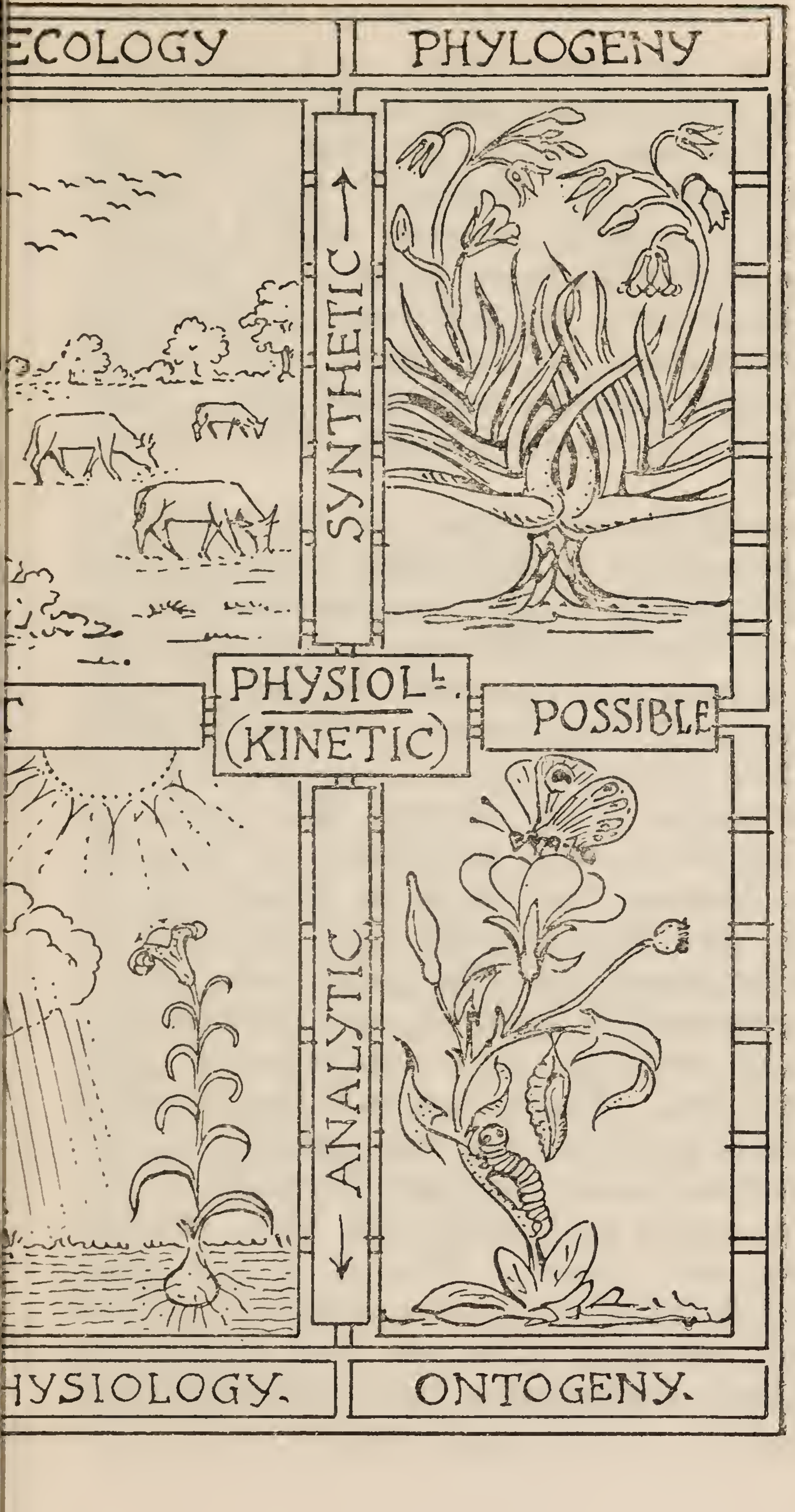
NOTE ON DIAGRAM I.

I. The first diagram is intended to illustrate the (eight) sub-sciences of Biology :—respectively analytic or synthetic, static or kinetic, in past or present, or in change.

Static aspects, in past or present. MORPHOLOGICAL SUB-SCIENCES	Thus for	ANATOMY . .	A Bird's Skeleton. Here should be included HISTOLOGY.
	" "	TAXONOMY . .	Examples of Bird Types in Museum.
	" "	EMBRYOGRAPHY .	Development of Frog.
	" "	PALEONTOGRAPHY	A Trilobite, representative of an ancient Arthropod race.
Kinetic aspects, Present or Possible. PHYSIOLOGICAL SUB-SCIENCES	" "	PHYSIOLOGY . .	A Living Plant in sunlight and shower (for study of Life-processes in detail).
	" "	ECOLOGY . .	Life in Nature ("Natural History").
	" "	ONTOGENY . .	Individual development interpreted. (Herbert Spencer's symbol of Evolution — caterpillar, pupa, and butterfly.)
	" "	PHYLOGENY . .	Suggestion of part of a "Genealogical Tree"; with its branching and leafing.



PALÆONTOGRAPHY
TAXONOMY
GROUP
PAST
MORPHOL[L].
(STATIC)
PRES
INDIVIDUAL →
EMBRYOGRAPHY.
ANATOMY



ECOLOGY
PHYLOGENY
SYNTHETIC
PHYSIOLL.
(KINETIC)
POSSIBLE
ANALYTIC
HYSIOLOGY.
ONTOGENY.

dietetics in the first place, and the latest delicacies of the season only in the second.

How then are we to set forth the vast literature-feast of biology? Not merely classified in orderly fashion, with Linnæus, but now in evolutionary fashion, in which—with all respect to philologists, historical philosophers, etc., on one hand, and on the other to astronomers and geologists, biologists are in the main leading, since Darwin especially.

But evolution is a theory of life's history, and up to man's: so its literature, and indeed that of all biology, needs to be presented in evolutionary order too. We have noted the classificatory primacy of Linnæus; but now see his bibliographical significance. He assimilated the work of his predecessors, henceforth for us his Precursors. But beyond this work, as Editor of their best contributions into his *Systema Naturæ*, he was here, above all, an Initiator, and this so fully that we date all modern taxonomy from his great book, henceforth recognised by botanists and zoologists all the world over as the year one of their taxonomic era. But he not only incorporated all he could get from his contemporaries, but sent out his young disciples throughout the world to search and collect for him—witness Thunberg and others. Thus is it not plain that the latest finder of a new species anywhere is a Continuator of Linnæus, and amplifying his initial herbarium, his corresponding museum?

Bibliography in Principle and in Practice.—Note now that this is no mere history of botanical or other collecting; but that it raises a great principle for the rational bibliography of our science; that is, for grasping its whole development; and with more learning than ever, and more lucidity too. Precursors, Editor and Initiator, Continuators, are here the essential *dramatis personæ*; and in what field of knowledge shall we not find the like?

Pass now from classification (Taxonomy) to natural history (Ecology). When Linné had classified horse and donkey as *Equus caballus* and *E. asinus* respectively, and tersely described their essential differences, he was done with them: but Buffon gave us the most vivid of accounts of horses and their ways, and these throughout civilisations. Beyond editing his precursors, he was thus also an initiator, with continuators ever since.

Now pass to physiology, with its foremost historical event, and masterwork, Harvey's *De Motu Sanguinis*, setting forth the circulation of the blood. For this there were precursors not a few, but for a simple example take Steno, who studied with care the valves upon the veins (so easily seen to set up swellings on their course when one presses a finger across one's fore-arm).

Harvey had his continuators, verifying and extending his work: as notably Hales: and he also, by first observing the ascent of sap, became no small Initiator on his own account of a new yet parallel library-shelf—that of Vegetable Physiology. For Harvey's most important early Continuator take, however, Malpighi, with his observation of the circulatory process in the frog's web. In discovering the capillaries between arterioles and veinlets, Malpighi completed Harvey's argument by ocular demonstration. For a modern continuator take Marey, with his developed sphygmograph, by which the pulse is made to write its record, thereafter decipherable not only by the physiologist, but invaluable to the heart-physician. Like Malpighi, Marey is thus not only a continuator, but a re-Initiator, since advancing Harvey's line.

Here we have said nothing of Harvey's mere Commentators, nor of his many critic opponents, since these have long lost interest: yet the collector-librarian preserves these for the historian's occasional reference.

But there were physiologically-minded physicians long before Harvey: so back to great Hippocrates, whose books are on the shelf above, an Initiator beyond all, though doubtless editor of preceding writers, who since matter little. Expositors and Commentators have abounded, but worthy continuators and re-initiators (save Galen, himself long ignorantly worshipped) essentially appear with modern times.

Anatomy had, of course, its ancient precursors, as from mummy-makers to Galen especially: but Vesalius, essential Initiator, only comes with the sixteenth century's renaissance of science. After him, indeed, the literature of human anatomy is essentially the historical series of his continuators, though, of course, with sub-initiators too.

It was left to a contemporary of Vesalius, the all-round Nature-student Pierre Belon (1514–64), to be the precursor of comparative anatomy; with his famous copper-plate of two skeletons, bird's and mammal's, with their main structural correspondences, as of wing and arm ("homologies" as Owen correctly called them, as distinguished from physiological *analogies*, like wings of bird and insect), clearly shown; a new start in biology, rightly commemorated by a statue erected a generation ago in his native town by naturalists all over the world. But despite further precursors, the great editor-Initiator of comparative anatomy only comes in the nineteenth century—Cuvier with his *Règne Animal*. For he was not only foremost among his contemporaries, but inspiring to successors, like Owen in this country, and then Huxley.

We are thus fairly beginning a card-catalogue of historic interest, and we can likewise lay out in order in any department of study its essential historic series of books for exhibition, from precursors to initiator and main continuators, with typical papers up to date. This is of interest to our students and stimulus to ourselves, since it affords vivid presentments of the progress of this and that important line of thought and work, and an impetus towards more. Thus already for taxonomy, in the orderly heritage of which Linnæus' works are central, and for ecology, in which Buffon's, and above all Darwin's, stand so high. Conveniently ranging morphological works on the left hand of our bookcase, and physiological on the right, we now occupy descending shelves, below those of life-wide and world-wide (Linnean) taxonomy, and its corresponding (Buffonian-Darwinian) ecology.

In this lower series we have now first to place the observation and interpretation of individual beings, seen as living wholes. Hence on our first shelf comes foremost among initiators Hippocrates the great, as the next, and yet in some ways greater, initiator called him (the medically educated), Aristotle, " father of all who know "—biology thus far from excepted. Of commentators of these two masters there were, soon and since, too many; but of true continuators till comparatively modern times too few: so enough here to note his heir and peripatetic successor, Theophrastus, with his History of Plants. Yet as nearly five centuries later Dioscorides, with his *Materia Medica,* achieved greater renown and longer influence, his descriptive work may well stand on the corresponding left-hand level, though on this side too its prime occupant must again be Linnæus, whose individual descriptions are our exemplars truly classic.

On the next level below these, let us place the works of Anatomy proper—for the anatomical discrimination of each individual organism—man, animal and plant—into its essential parts, its Organs. Beyond its start with the mummy-maker's papyrus, and with other precursors, and past Galen and his continuators and commentators *ad nauseam*, we have at length Vesalius re-initiating human anatomy, thenceforward increasingly progressive; and at length too, through Belon and others, Cuvier and his successors. Nor can the botanist omit here the initiators of the "Natural System," De Jussieu, father and son, the more since it was finding the latter's treatise on a book-stall that started the young Cuvier upon his fertile career. Our bookcase has thus to develop lateral shelves: and so too on the corresponding right-hand level, for physiological comprehension of organs in their functioning: for, as we saw above, Harvey not only found a continuator in Hales, but started him as main initiator of vegetable physiology, a department later in developing, but increasing since the late eighteenth century, and now more than ever.

All these shelves have gone on filling; but the next deeper one was started by Bichat, that most brilliant of young anatomist-physiologists too early lost, whose memorial not only rightly stands central in the Paris School of Medicine, but was renewed by Comte's taking him as the ideal exemplar of the spirit of modern science at its best, as well as of biology in particular. Why so?

Not only because of his interpretative "physiological researches on life and death," but of the great step made in his *Anatomie Générale* (1801) as reducing the complex structures and functionings of the organs, hitherto only considered as wholes, to those of their essential components, the simple and, for him, elemental Tissues, of which he showed the organs variously built. A simple idea nowadays, but the essential start of a truly scientific Histology (hence named web-lore), since at once anatomist and physiologist together thus progressed from merely naming and knowing the particular organs, *e.g.* those called muscles, to studying muscle —as muscular tissue—and striving, as they do still, to correlate its subtle texture with its contractile powers. Thus Bichat substantially deepened our bookcase, by his initiative on both sides of his new shelf.

But for a century and a half before this, microscopists had been busy, with their then "new eyes," disclosing a new world. Plant sections especially revealed to Hooke and Grew, to Malpighi also, minutely chambered structures, which they likened to the little and well-walled cells which make up a great monastery building. Leeuwenhoek, as early as 1674, discerned what are now so familiar to us as single-celled organisms, and even discovered bacteria: while Fontana had detected the "kernel" of the cell, more than a generation before Robert Brown showed its normal presence as "nucleus." Here then are notable precursors, by whom Bichat had already profited. Moreover it is here worth noting that only eight years after Bichat's work, Lamarck's *Philosophie Zoologique* (to which we must come later) contained this striking statement, "No body can possess life if its containing parts are not a cellular tissue, or formed by a cellular tissue": while in the same year Mirbel's *Théorie de l'Organisation Végétale* affirms, "The plant is wholly formed of a continuous cellular membranous tissue." But only with the subsequent nineteenth-century improvement of the microscope could this new and deeper shelf, for the structures and the functions of the cell, begin its more adequately concrete filling. In 1838 Schleiden proved that the embryo-plant arises from a single cell, and thus its subsequent tissues; while in the next year Schwann generalised this for the animal world also; and thus we have the "Cell-Theory" and its maxim—*omnis cellula e cellula;* ever since a matter of common knowledge, yet fairly described by Agassiz in his day as "the greatest discovery in the natural sciences in modern times." Hence on the physiological and even pathological side we must name Virchow, whose *Cellular Pathologie* not only ably summed up the essential cell-theory for the origin of all tissues, the normal and pathological alike, but also deepened the whole understanding of disease, from temperamental, humor-ist, or organ-ic, to histologic proper;

i.e. to disturbances of cell-function and cell-structure.

Along this Cell-shelf, and particularly on its structural side, has ever since been following a wealth of continuation researches, too numerous for outline here and still in active progress, especially with the ever-improving microtechnique, which now displays minute refinements of cell-structure and nuclear division far beyond those of our comparatively recent memory. And all with vast and ever-increasing contributions, papers without number, great and small, yet not beyond classifying and cataloguing on this same simple historic principle—the Natural System of bibliography. Yet while the cell-theory was coming to birth, a yet further analysis was working, and towards a deeper shelf accordingly. Dujardin in 1835 described the living stuff of Protozoa and other cells as "sarcode"; and his pioneering was ably followed by German workers. Thus Von Mohl (1846) especially emphasised this in plants, as "Protoplasm," vitally important within its mere cell-walls; though only in 1861 did Max Schultze clearly establish the modern conception of the cell as a unit-mass of nucleated protoplasm. Since then we no longer think of "the Cell containing protoplasm," but of the nucleated Protoplasm which constitutes and gives function and form to the cell, unwalled, or walled, as it may become (and at length even empty of protoplasm in many plant-structures).

Is our descending analysis now complete? Yes, and no: for though in histological analysis we are still on this protoplasm level, however much we may scrutinise and speculate into its finer texture and mixture, we must next call in the chemist and physicist to our aid, towards explaining such mass-composition by help of their molecular experience, and its vividly visualising powers. For such analytic elaboration we must evidently allot a final shelf. Indeed, its right-hand physiological half has long been filling. We have hitherto been locating the familiar functions of living bodies—respiratory, circulatory, alimentary, excretory, etc., and reproductive—upon each level of our descending analysis from Organism to Organ, Tissue, Cell and Protoplasm; so we need this final shelf for a correspondingly intimate enquiry into the essential chemistry and physics of protoplasm, and thence back to cell, organ, etc., in all their functionings of life. It is indeed well nigh two generations back since this problem was broadly and comprehensively stated; first by Claude Bernard—probably among all physiologists as yet the mind of fullest range. Thus he made great initiatives, as of unravelling the previously obscure functions of the liver, of linking up animal and vegetable physiology, which had been too much studied apart; and he penetrated below all such physiological functionings, in living tissues, cells and protoplasm, to their essential chemistry itself. For he came to see all functionings as various expressions of the general processes of chemical change, which he generalised, therefore, as "metabolism." Its varied processes he distinguished, as being in the main either constructive or destructive, upbuilding or downbreaking, synthetic or analytic—in short as of "anabolism" or of "katabolism." This simplified, yet deepened, way of viewing and interpreting physiological processes proved ahead of his time; but a good many years later it was restated by Hering, and further emphasised by Gaskell. It is now familiar in principle, though it is still very far from adequately elaborated and applied. It proves fruitful, however, and in many directions: thus, to cite only one, it is fundamental to the interpretation of the evolution of the sexes (females more anabolic, males relatively more katabolic), which is offered in one of our preceding volumes in this series (*Sex*); and this same essential contrast is similarly utilised towards an evolutionary interpretation of the origin of varieties, species, genera, and types, in its companion-volume (*Evolution*).

The Bookcases of Biology.—Is our bookcase at length completed? Enough at least to present it in diagrammatic form (Diagram I, pp. 49, 50).

Taxonomy is thus clear; with its ascending and increasingly comprehensive syntheses of individual forms, not only into pairs and families, but into varieties, species, genera, orders, classes, sub-kingdoms or phyla, these to Animalia and Vegetabilia, and finally these again to Organisata. For this was Linné's final generalisation, emerging from the ancient alchemistic and still-surviving tradition of "three Kingdoms of Nature," by thus uniting the two living ones, in clear contrast to the non-living mineral one, his Conserta.

Similarly we have before us our outline-library of Ecology, again ascending, from ways of pairing and young-producing, to the struggle for existence among varieties, species and types, with all their varied adaptations, their specific co-operations also, as of "mutual aid"; and all their many inter-adaptations, as from the ugliest parasitisms to the most beautiful correlations, as of flowers and insects. And supremely, of course, the world-adaptations of plant and animal life; and not only to each other, but to earth's crust in great strata, like plant coal and animal chalk, coral-reefs and limestones; and thence even to the evolution of the present atmosphere itself. On the widest ecological levels, as with the most intensive physiological analyses, we are thus interpreting the processes of life in relation to those of the non-living world. Thus the biologist must needs apply his mind to the inorganic sciences.

Here, beyond the essential ideas of both synthetising and analysing life's functionings and life's structures, we are having the time-process brought clearly before us; and this through cosmic time—the immeasurable geologic past. Hence for this largest-scale history we have to add to our Linnean taxonomy, which was only of the present, the whole past of life; and as biologists, we cannot be content with leaving fossils to the geologists (William Smith as initiator for choice) as so many landmarks for identifying strata. We have also to incorporate them into our taxonomy; and this was the essential initiative of Cuvier, thus (though not without precursors as far back as Palissy, and even Leonardo) the father of Paleontology. Despite the innumerable "imperfections of the geological record," which we shall always have to deplore, the history of life is opening, and often surprisingly; and this not only from extinct Protozoa and Protophytes, sponges, corals, worms, crustaceans or again the queerest fishes, all arranged with their respective congeners and kindred of to-day, but also for higher forms. Besides the Protean variety of amazing monsters of land and sea and air which have long vanished utterly, and no longer point anywhere, we are also finding from time to time what are plainly "missing links," to fit into the gaps of our taxonomic series, such, for instance, as the reptile-tailed and strong-toothed bird, well named Archaeopteryx; and, most interesting of all, forms variously akin to man himself; as notably Dubois' strangely man-like ape from Java, *Pithecanthropus erectus*, and the somewhat brutish, yet essentially human *Eoanthropus*, him of the ancient

Piltdown skull. And now that such few discoveries are incentive to world-wide research, we may well anticipate the unearthing of further treasures of paleontography.

But quite apart from this history of life on the great scale, when was not man interested in his own particular life-history, and in that of his mate and offspring?—as also, for the most practical reasons, in those of his domesticated animals, his cultivated plants, not to speak of the seasonal and organic histories of the animals he preyed on, the plants he gathered from, in far earlier days? Beyond all, however, he has been curious as to the mystery of human birth, and of origin and growth before this.

The all-round interests of Aristotle's observation and reflection could not miss such problems; yet despite him and later precursors, the modern initiator was essentially Harvey.

We have now enlarged our bookcase by a double series of shelves, for Paleontography with its past form-groups, and, below this, for Embryography with its transient form-phases, so that our Taxonomy has now an historic illumination, and our Anatomy is enriched by a literally bio-graphic one.

Is this at length all biology has to do with? For long it seemed so: yet man lives not only in the present, nor even with memories of his past: he is always changing, *learning*. Through childhood and in youth he aspires, and this towards fuller development; and as he matures and ages, he sees how others change as well as himself, and likewise his society too—and all this with increasing depth of feeling, of fears and hopes clouding or brightening the unknown way. His present thus does not merely recall and question into its past; it cannot but also peer towards the future. The great rule of science—observe to understand, understand to foresee—and with this even that of applied science—foresee to provide—(in summary, *voir, savoir, prévoir, pourvoir*)—have thus been essential factors of simple human life, from long before the days of any conscious science at all: and we have but to "go to the ant" to realise that she sees and provides, however little of our conscious human understanding and foresight our post-Solomonic psychologists may grant her.

Given then our human interests in individual development, and in its decline also, in group affairs, and these also for better or worse, the wonder is not that these should have been turned to the questioning of all forms of life, but that Solomon's counsel was not followed far sooner, and further than his ecology. At length, however, we have these twofold, yet inseparably associated enquiries into life's becomings—in individual and in group, emerging as observant, orderly and rational, sub-sciences. These enquiries have been long delayed, by prolonged outlook into the mythologic past, and thus not only by the Babylonian story of Creation, but by its " Miltonic " statement, as Huxley was wont to call it. But thanks not only to advances in other sciences—astronomy and geology on the naturalistic side, philology, history and others upon the humanistic—but also to liberation common to all these through social changes, and their interpretations, stated, however vaguely, as " Progress "—our biologic enquiries have turned more and more clearly towards understanding the organic progress (for biology, however, including decline as well as rise) which we call Evolution. To understand this, and its rationale, for the different species and groups of life, is termed Phylogeny (race-genesis); which rationalises, as far as may be, our previously but descriptive Paleontography into Paleontology proper, and with this our (enlarged) Taxonomy together. The complemental enquiries of Ontogeny (individual genesis) are towards rationalising our empiric observations of individual development (Embryography), and thus explaining its changes and phases, as Embryology proper. These two evolutionary sub-sciences have to be taken together in their full and united sweep, as Evolution. Yet in this field we have to go beyond the earlier view of evolution—so predominant, and indeed so necessary, since Darwin's day—as essentially an historic enquiry into origins: to turn these forward, more and more clearly—as applied biologists, first breeders, and now also eugenists, are insisting—towards discernment and interpretation of the tendencies and potentialities of living beings, and even of man himself. Here Nietzsche, despite his limitations and faults, and these summarised and idealised into his super-man, was undeniably a humanistic path-breaker for the evolutionary spirit, though this must work its way in the patient manner of the sciences.

Thus, for instance, our studies of the variations of animals and plants, and these both free and in domestication, cannot too thoroughly and extensively continue Darwin's: nor similarly can the investigation of heredity be too profound, as Mendelians, so far beyond Galtonians, are now daily proving. But variations are full of tentatives towards opening adaptations. Heredity has not only continued the past, and stamped its likeness upon the forms of each succeeding present, but it has in it the momentum of life; and why not an urge of variation as well? Heredity, for each stock, has been summed from life's past variations, and thus is but their resultant. Its comparative stabilising and keeping of variations within bounds has thus itself evolved, in course of many generations. But this stability, by the very nature of things, things organismal as well as environmental, is best maintained in persistent conditions, like those of the Cambrian lamp-shell (*Lingula*), to this day so settled in its mud. We shall come later to fuller outline of these questions; enough here to note their futuristic trend; as well as the historic (and thus originative) interest of variation and heredity in their continuous interactions, past, present and possible.

The Library of Biology, and in Use.—At length, therefore, we have our bookcase completed in outline, to house the whole bibliography of the eight sub-sciences we recognised at the beginning. In simplest schema, apart from parallel shelving for the respective departments of group-studies in ascending synthesis, and of individual studies in descending analysis, we have thus space, in orderly fashion, for

Paleontography.	Taxonomy.	Ecology.	Phylogeny.
Embryography.	Anatomy.	Physiology.	Ontogeny.

This schema, transferred to a sheet of paper folded vertically into four, can now be placed erect; so now it expresses, in miniature model, the four walls of our biological study-library, of which each has its lower and upper bookcase. It will help clearness to think of this as also a lecture-room, with the entrance left open, at the corner next the speaker. We thus first see—on the opposite and right-hand walls—the cases of the four central sub-sciences, those of life's forms and functionings, the activities of races and of individuals, in the present. Next, as we go in, we notice, on the left-hand wall, the literature descriptive of life's past, again for races and for individuals. But it is only as we turn to sit down that we see the fourth wall, with its twofold literature of Evolution (and even its blackboard for its exponent). Thence, starting from such tracings-out of racial origins and individual developments, and these taken together, we more fully appreciate the significance of forms passed away, and of individual phases gone through; and we thus come to understand present organic forms, and their detailed analysis, more clearly. Conversely, too, we can now turn our eyes to our left, and look from the evolutionary shelves to those of Ecology and Physiology; and thence again turn our heads back to Anatomy and Taxonomy, since function has to interpret structure. Thus, in short, we are coming (by every way, and with more comprehensive vision) to fuller grasp of what is as yet known of life, and with clearer recognition of its many and various problems, incompletely solved though they may be.

Upon the table of this room, we may now look at any specimen, fossil or contemporary, its group-type also; and so for all other finds or searches. In every case we shall now see their significance more fully, by help of all the distinctive view-points recorded and expressed around us; these not only the general ones of each wall and half-bookcase, but of each shelf, and even of its minor sub-groupings. Thus, if lucky quest has brought us a new species, we have obviously to add our fresh page of description and illustration to the long range of previous continuators of the *Systema Naturæ;* while a new point of human anatomy fits into, or on to, the long line marked by Vesalius' masterpiece. And so on for each sub-science.

Even for the finer sub-specialisms, which this or that shelf has developed or may require, provision is possible. As a note-worthy step towards this completeness, we have a suggestive example in Sims Wood-head's admirable compacting of his Patho-logical Library at Cambridge; for there the shelves are not ranged upon the wall as in simple library rooms, nor even shelved in narrow transverse passages walled by shelves as in the book-stores of modern great ones, but now as side-cases, recessed closely together, yet on rollers, so that any sub-group can be brought forward and consulted, yet run back when done with; out of sight, yet as safe as may be from oblivion, and even from its dust. Here in principle—indeed well-nigh literally—are the very "drawers" to which Napoleon compared his orderly and clearly controlled mind; thus explaining his varied powers, alike of special concentration and of generalising mastery; and even, "by closing all at will," his command of sleep.

Our arrangement works then, whether for teaching or writing, for research or freshening speculation. For all these our library is equally adaptable, since related to museums and laboratories; and, like them, windowed, and opening into Nature.

Yet also, in another mood, we may imagine all these gatherings from her to condense, and to combine, into a great thought-organ, of as many pipes and keys, and stops and swells. For our classifying, the Linnean stop (with minor changes and additions) remains fundamental; and so for our anatomy the Vesalian or Cuvierian series; for our physiology the Harveian; and for evolutionary thought it may be at times the Lamarckian, though more commonly of the Darwinian series. Thus every fresh contribution to the science, or re-statement towards its exposition, though necessarily in keeping with the larger whole, acquires more or less individual presentment too, something of personal equation, as even with the most faithful nature-draughtsmen. Indeed as nature-mastery grows with practice and powers, and all these with interest in humanity—for biology initial, and also ultimate—range of subject and individuality of expression increase together, as with every art-work of old or later days. And as the psychologists are now bringing their own organ-rebuilding into fuller adjustment with that of biology, new voluntaries increasingly appear; until even, in the more idealist of these, we hear anew the Vox coelestis jubilate, however may, in these sad years, the Vox humana wail.

CHAPTER III

ILLUSTRATIONS FROM RECENT MORPHOLOGY AND PHYSIOLOGY

Biology in Progress.—It is now full time to be seeing more of what the various sub-sciences of biology have to tell us. Yet in evolutionary fashion, let us recall their simplest beginnings, even with child-experience of them.

Has our long-laboured graphic outline of eight sub-sciences seemed but cold, dull, and "dry"? If so, the magic of graphics (for graphics have always been magical) has not yet been realised. For these eight bookcases are likewise windows, each and all; indeed magic casements, though opening not on perilous seas forlorn, but upon the full wonder and beauty of Life. Even that so formidably named Paleontography, and with only dark strata-panes to peer through, reveals forests exuberant beyond ours, and monsters stranger and more terrific than the very dragons by Saga-heroes slain. Taxonomy?—here are the long perspectives of the Wonder House, as the simple and wise folk of an Indian city and countryside call its museum. Ecology stands open to the Nature-Drama, not only day and night, but throughout the seasons; while of all these windows that of Evolution brings most of light, and even its brightest beam.

Again recall our early joy and child-wonder over our first fossil!—an unforgettable experience none should be allowed to miss, the more since, henceforth or later, of talisman-key to the immeasurable past. Recall too our first collections of shells and seaweeds, of gay butterflies, of beetles glittering or grim. For Ecology, not only our Nature-stories, but our own first making of them; as by day round Robin's trustful friendship, at night from the cavern fears so deep fixed in our race. And even for Evolution there are moments which every child at times has, as probing and questioning philosopher—Who made all this? —How came things so?

Thus too even for Embryology. How is it I am here? For did we not wonder over our own life, and how we came by it—and whence this amazing arrival, the new baby? For Anatomy, the bird's skull or rabbit's bones we found, and perhaps next the weird skeletons of Holbein's Dance. For Physiology our own breath, heart-beat, sensations, our ailments too; and the vague anxiety of something wrong with mother; and, for Ontogeny, of course, our dreams of what we are going to grow up to be, and do; and how?

So now—and as far as may be with this old spirit, continued and developed as becomes children of larger growth—let us hear something of what the big naturalist-children have of late been hunting up, and finding out, and writing down.

Let us ask, then, how the eight sub-sciences of biology are represented in the investigations of to-day. Progressive biology may be compared to the growing-point at the tip of a stem, a dome of young and active cells, growing and multiplying, and giving off on all sides the little rudiments which differentiate into leaves. We have mapped these leaves in four pairs, and as octants of our sphere of knowledge: as

PALEONTOGRAPHY.	TAXONOMY.	ECOLOGY.	PHYLOGENY.
EMBRYOGRAPHY.	ANATOMY.	PHYSIOLOGY.	ONTOGENY.

We have also shown how there must be these sub-sciences; and it follows that (unless dormant) they must be represented in the biology of to-day. According to the social environment, the needs of the time, the invention of new appliances, and the particular interests of the leaders in discovery, the emphasis is bound to shift from one sub-science to another. It differs from time to time and from country to country. In the days of F. M. Balfour, and indeed afterwards, one could hardly think of embryology without Cambridge; but that emphasis has now shifted elsewhere, and it is Cambridge and bio-chemistry that most workers would associate together. The biologists of America were for many years predominantly taxonomic, with Alexander Agassiz and Asa Gray as distinguished leaders; they next did wonders for paleontology, and now their conspicuous emphasis is on experiment.

Besides the influence of dominant personalities in turning the eyes of discovery in this direction or in that, a modifying factor is to be found in the needs of the time and of the place. It becomes important, let us say, to make it easier for white men to work in the tropics without rapid loss of health; this prompts enquiry into tropical diseases, into the life-history of their microbes, into the habits of their "carriers," like Tse-tse flies, which disseminate the sleeping sickness Trypanosomes, or mosquitoes, which do the same for malaria organisms. Thus arises a new Protozoology (both Trypanosomes and malaria microbes are Protozoa, not Bacteria): fresh impetus is given to entomology, which becomes more precise than ever, and to an ecology which is often subtle in its linkages.

To think of Biology in Italy is to recall the splendid monographs in which the workers at the Naples zoological station have described the rich fauna of the Mediterranean; yet this is not the most characteristic feature. A survey of the transactions and proceedings of the learned societies of Italy will show that for many years the emphasis has been laid on entomology, acarology, and parasitology. The urgent motive has been the protection of the olive and the vine, not forgetting the silkworm. It is similarly quite natural that British zoology should have a high reputation in connection with fishes and marine ecology in general.

Another factor determining emphasis is the invention of some new appliance. When the microscope disclosed a world of previously invisible life and the fascinating intricacy of minute structure, there was a tidal wave of enthusiasm. This waned, however, and the microscope became as familiar as a hand-lens, and an indispensable instrument of research. Improvements in lenses, the invention of the microtome, and the elaboration of technique, *e.g.* particular stains for various tissues and even various parts of the cell, created a fresh wave, a new period of enthusiastic cytology. But the explorers of the microcosm of the cell were often led astray by the very elaborateness of their fixatives and stains; for they too readily mistook for natural intricacy what turned out to be "artefacts," mere post-mortem appearances. It was found that protoplasm in the living state has the properties of a colloid system, and seems structureless under the best microscopes, with ordinary modes of illumination. This involved the rejection of much of a large shelf of cytological literature; but it led to a critical revision, and here there has been fresh impulse from the invention of the ultra-microscope, which projects a very intense beam of light horizontally through the protoplasm and illuminates particles too small to be seen with an ordinary microscope. Thus a new trail is blazed, and the study of protoplasm recommences anew.

Illustrations from Morphology.—What is the structure of this organism, as a whole, and in each of its parts?—that is the morphological question which must continue to be asked as long as there are new forms to describe and anatomise. Thus the morphological botanists and zoologists of to-day continue adding their pages to the great monographs of previous centuries.

Though emphasis has shifted from the study of form to that of function, the anatomists and histologists are still busy, and even those whose interests are predominantly physiological admit the value of the morphological discipline, and the need of intimately knowing the structures whose activities are to be investigated. Certain cells in the wing of a White Butterfly produce a fragrant scent, by which kin calls to kin; but to understand this physiological fact aright we must turn to the entomological microscopists, who show us, in the scented wing, its highly specialised structural arrangements. They describe platelets, each with hair-like filaments, a fine flexible footstalk, and a basal disc, fitting into a socket, within or beneath which lie the scent-making cells, whose secretion is thus given to the air.

Especially when there is a discovery of a distinctively new type, such as the giraffe-like Okapi from the West African forests, the comparative anatomist, in this case

Lankester with his monograph, must give his morphological account of it along the customary lines. Thus too he is continuing the anatomy of Huxley, as Huxley had followed on Owen's, and Owen on Cuvier's. That new ideas may lie behind even the descriptive work of each generation is obvious; but, after all, dissection remains dissection, whether the scalpel is in the hands of Aristotle or Galen, Hunter or Huxley. Among the new types of comparatively recent discovery a few may be mentioned. (1) There is the remarkable Cephalodiscus—first dredged by the "Challenger," but since found abundantly at the Cape—a curious colony of small animals which are related to Balanoglossus and other pioneers of the backboned animals. (2) From among the transparently delicate, free-swimming, luminescent Ctenophores of the open sea there have diverged remarkable creeping forms—Ctenoplana and Coeloplana—which seem to point the way to the Planarians, the most primitive of worms; and this abandonment of active pelagic life finds its terminus in Mortensen's Tjalfiella, which, after its early motile stages, is actually sessile. (3) Remarkable on a very different line is a little creature (for its lack of antennae, called Acerentomon) which seems to be a precursor of winged insects, and, along with a few other kindred genera, is referred to a primitive order. It is blind and wingless, of elusive "cryptozoic" life, without breathing apertures, with simple suctorial mouth-parts, and, behind the usual three pairs of thoracic limbs that all insects have, it has four pairs of abdominal limbs, a unique feature for the adult insect state.

Improvements in microscopic and microtomic technique have made structural analysis more thorough than in former days. Thus many naturalists had carefully studied the lancelet (Amphioxus) before Boveri discovered one of its most interesting features—that it has ninety pairs of kidney-tubes (nephridia) with a close resemblance to those of some of the sea-worms. Amphioxus is one of the most perfectly known animals; for every fraction of a millimetre of its body has been scrutinised by the keenest eyes. The same may be said of Peripatus, a primitive type in the tracheate line of evolution, leading on to insects; and here again the discovery of kidney-tubes (nephridia) proved its affiliation to the Annelids, *i.e.* segmented worms.

Modern morphological analysis passes below the level of organs, and pushes to its microscope-limit, the exploration of the cell. Picture this cell-microcosm. A minute body of unmeasured chemical complexity, in a watery "phase," and with many different kinds of particles quivering in suspension—proteins, carbohydrates, fats, and waste products. In the centre of this whirlpool is the nucleus, surrounded by a semi-permeable membrane, through which there is a regulated exchange between the nucleoplasm and the general cytoplasm. But the nucleus is itself a little world. It contains a number of readily stainable nuclear rodlets, the chromosomes, usually definite in number for each species. Thus 64 is the number for the horse (the maximum for mammals yet observed), 48 for man, 24 for the mouse, but only 2—the minimum—for the threadworm Ascaris. Yet man's number, 48, is that of certain snails and also of a variety of banana; and the mouse's 24 are again counted in the lily. We do not yet see any meaning in such distant re-occurrences; the important points are (1) that the number is constant in all the body-cells of each species, and (2) that the ripe egg-cells and sperm-cells have always half that number. An interesting fact demonstrated by Prof. Ruggles Gates—and a possible clue to the mystery of chromosome numbers —is that allied species may be arranged in series, with the numbers of their chromosomes in some arithmetical order.

The chromosomes are so called since consisting in the main of protein substances, easily stained, and thus named chromatin.

Bathing the chromosomes is a complex nuclear sap (karyolymph), and there may also be a nucleolus, sometimes several nucleoli, but these are shown to be transient aggregations, some of reserve material and some of waste. Outside the nucleus, in the general cell-substance, there are in many cells definitely-formed granules and rods (mitochondria), which increase or decrease with characteristic metabolisms. Quite different are the chromidia, which seem chromatin-migrants from the nucleus, trying to colonise the cytoplasm. Much more than all this is to be seen in many a cell, without falling into errors of mapping out intricacies which may be but the artificial results of our fixing and staining. Very important are the minute "centrosomes" of most animal cells; for they behave like dynamic centres—"weavers at the loom" in Wilson's phrase—during the intricate changes involved in cell-division.

Each chromosome, under high magnification, even in the living state, appears as a series of minuter units, "microsomes," fixed on a ribbon of "linin," somewhat like beads on a string. When division occurs, each chromosome splits up the middle longitudinally; and the resulting halves distribute themselves to opposite sides with such meticulous precision that each of the daughter-cells gets its exact half of each. The same halving holds good even for centrosomes and mitochondria. The analysis of organism to organs, of these to tissues and to cells, is thus proceeding to nucleus, whence to chromosomes and their microsomes. Yet this analysis has to be continued to the physiological "factors" or "genes," smaller than microsomes, beyond visibility indeed, yet for good reasons generally assumed to be the vehicles of hereditary characters.

Illustrations from Taxonomy.—Whenever an expedition returns from exploring the depths of the sea or forests in distant lands, its collections have to be described and their specimens classified in the good old way. The zoologist or botanist becomes Linnean again, and adds his pages to the master-classifier's *Systema Naturæ*. Take one of the latest expeditions—a quick-pace visit paid by Mr. William Beebe, well named "travelling naturalist" to the New York Zoological Society, to the Galápagos Islands—"Darwinian Isles" to us, the "Enchanted Isles" of early mariners.

In less than a hundred hours spent on shore the party of collectors found 26 new moths, 8 new ants, 7 new beetles, 6 new mealy-bugs, and so on for other orders in smaller numbers. And, keeping up the pace, within six months of their return no fewer than twenty-two taxonomic papers were published or nearly completed.

Yet, contrasting the present with the days of our youth, we notice a great reduction in the appetite for "new species." A new form is no longer hailed as a trophy in itself; the first question is whether it fills up a gap in a series, or otherwise illustrates some evolutionary movement. As above noticed, there are interesting deepenings of species-description, even to chromosome-peculiarities. Thus Miss K. Blackburn has shown that in the genus Rose there is a series of species whose cells are built up on a base-number of seven chromosomes: *e.g.* a series of four species whose numbers of chromosomes are 14, 28, 42, and 56 respectively. The same phenomenon is observable in the Willow genus, whose species were at once the delight and the despair of the old systematists. The common threadworm of the horse occurs in two varieties, one with 4, and the other with 2 chromosomes in its body-cells.

Recent years have seen no great progress in regard to the larger taxonomic problems, such as the affinities of the greater groups, *e.g.* of vertebrates to worms. There is no new precision as to the affiliation of birds to reptiles, or as to the relationships of the different twigs on the Arthropod branch. But there has been marked success in working out more than plausible genealogical trees for smaller groups. Thus Petrunkewitsch has made a great step towards a natural classification of spiders; and the same has been done for sea-pens by the independent labours of Hickson and Kükenthal. Taxonomy continues, with increased penetration and precision, if with somewhat chastened ambitions.

Illustrations from Physiology.—The great physiological question is, How does the organism act or behave, as a whole and in all its parts; how does its vital activity keep going? Physiology enquires into the dynamical relations of the organism—its organs, tissues, cells, and protoplasm—just as morphology is concerned with their statical relations.

However morphological interests may have waned in the present generation, those in physiology have grown stronger. This is partly because the refinements of chemistry and physics have given the physiologist new methods, and partly because comparative physiology, having lagged long behind comparative anatomy and histology, now offers more promise of adventure and surprise.

Nothing has been longer familiar than muscle-contraction, in the past century the subject of hundreds of investigations; yet all the older work becomes relatively unimportant in the light of what was discovered in the early years of the twentieth century by Fletcher and Hopkins. They showed that there are two distinct chapters in the familiar process, one predominantly physical, the other predominantly chemical. In the first aspect, when each living thread of flesh-substance becomes shorter and broader, and thus does work, there is no using up of oxygen and no formation of carbon dioxide; there is only a liberation of lactic acid from within the muscle. Surface tension on the fibrils appears to change. What happens in contraction has been roughly compared to the uncoiling of a released spiral spring, save that the muscle-spring becomes shorter, not longer. If the muscle is to be restored to its original state of tension, and keep contracting, there must now be a chemical process, in which lactic acid (or some related substance like glycogen) is re-instated in the muscle. It may be that the energy derived from oxidation of part of the lactic acid set free is used to synthesise glycogen. In this process, which leads to a replacement of the lactic acid, there is a using up of oxygen and a production of carbon dioxide, but the muscle is not an internal combustion-engine, as was formerly supposed. As Sir William Bayliss put it, "The muscular system is analogous to a gas-engine used to compress air into a reservoir, from which it is taken to drive, by its pressure, various machines and tools."

What was begun by Fletcher and Hopkins has been continued by A. V. Hill, Meyerhof and others; and yet no physiologist would say that he quite understands the chemistry and physics of what in an earlier stage of the enquiry was simply accepted as "contractility." One cannot expect an understanding of the process to be easy; for, as Sherrington has said, "The engineer would find it difficult to make a motive machine out of white of egg, some dissolved salts and a thin membrane," which is practically what Nature has done in muscle. We cannot pass from this glimpse of the secrets of the most familiar process in the animal world without recalling that we have been speaking of what Bacon called "the hidden motions of things"—the changes that underlie the throbbing of the medusa in the tide, the laboured crawling of the earthworm, the fluttering of the butterfly over the meadow flowers, the leaping of the salmon at the falls, and the way of the eagle in the air. It is the problem of Life in motion.

In the year of the publication of Darwin's *Origin of Species* (1859), the great physiologist Claude Bernard stated clearly that various organs of the body, such as the pancreas, produce what he called "internal secretions," which are carried away by the blood. The idea was generalised—in fact over-generalised — in 1891, by Brown-Séquard and d'Arsonval, who suggested that "every tissue, indeed every cell of the organism secretes on its own account certain products, or special ferments which are poured into the blood, and come to influence through this medium all the other cells, giving them a solidarity different from that due to the nervous system." Thus there were precursors of Bayliss and Starling, who discovered in 1902 a new secretion affecting the activity of pancreas; and thence developed the too vague concept of secretion-influences into that of definite chemical "messengers," which play important parts in the co-ordination of the activities of different organs. For such a chemical message-stuff they adopted the term "hormone" (which means "arousing to activity"); although, as someone said, they should have called it "hermone," after Hermes, messenger of the Gods. Sir Edward Sharpey Shafer next suggested the complemental word "chalone," which means "depressing"; for some of these chemical messengers are as powerful in quieting down or inhibiting, as others are in arousing. But the term hormone holds the field.

The story of Bayliss and Starling's first hormone, above referred to, is well worth telling, even in abbreviated form. In the region of the food-canal immediately after the stomach, some of the lining cells produce in minute quantity a hormone (" secretin "), which is delivered, not to the intestine, but to the blood. It is thus carried everywhere; yet, like a Yale-key seeking its appropriate lock, it finds this essentially in the pancreas, the most powerful of the digestive glands. The hormone here excites increased production of pancreatic juice, which is poured into the food-canal, and thus promotes digestion. This secretin formation occurs when food, acidulated from the stomach, enters the beginning of the small intestine. This is a clear case of physiological correlation, in which intestine and pancreas work together. The only other organ besides the pancreas that the secretin affects is the liver, whose bile-secretion, thus increased, gives some assistance to the pancreatic juice.

The organs or tissues with internal secretion are technically called " endocrinal," and they are usually ductless. Though the pancreas has a duct for its digestive juice, its internal secretion, yielding the now famous " insulin," is carried away by the blood. Other important endocrinal glands are the thyroid, the supra-renals, and the pituitary. The thyroid gland—a small-paired body on each side of Adam's apple, produces a hormone widely regulating the chemical routine of the body, and either its deficiency or its exaggeration spells disaster. The central part of the supra-renal bodies—which lie just in front of the kidneys—produces adrenalin, a very potent hormone, whose secretion is greatly increased by strong emotion, such as fear or anger. This increase of adrenalin brings about a rapid rise of blood pressure, quickens the breathing movements, enhances the excitability of the skeletal muscles, as well as their power of resisting fatigue, with other rapid changes invigorating the body. So if righteous anger has stimulated this hormone production of the supra-renals, the result is the preparation of the body for a fight. We see its effect even on the tiny erector muscles of the hairs when the annoyed cat makes itself large before the dog. Adrenalin is now made synthetically by the chemist, and is sold in the shops as a means of stopping slight hæmorrhages, such as nose-bleeding. Besides adrenalin, the only other hormone that has been isolated and chemically analysed is the "thyroxin" of the thyroid gland. It is rich in iodine, and an important point is that it can be readily given along with the food to a patient suffering from thyroid deficiency.

The hormone of the pituitary body, which projects from the under-surface of the brain into a little cup of bone, has much to do with the regulation of growth. Too much of it may lead to the growth of an unhealthy lethargic giant; too little of it may mean the development of an unhealthy dwarf, slow of pulse and weak in energy. It has been suggested that the extinct giant Reptiles of the Jurassic and Cretaceous ages suffered from an exaggeration of the pituitary body.

But this remarkable organ is also concerned with the regulation of what happens to the starchy and sugary food. This illustrates the complexity of the internal economy, for thus one and the same endocrinal gland may produce more than one hormone, and different hormones often seem to corroborate or counteract one another.

Of great interest are the hormones which are carried by the blood from the reproductive organs, and distributed throughout the body, awakening the adolescent changes in their manifold expression. The male frog's swollen first finger, the nuptial adornments of many cock-birds, the antlers of stags are familiar masculine peculiarities, activated by their reproductive hormones. In many cases a female organism has masculine characters lying latent, because inhibited by " chalones " from the ovary. This explains how a duck from which the ovary has been removed may put on the brighter livery of the drake and assume some of his ways as well. Common fowls may also show the like.

Not less important are the hormones which prepare the mammalian mother for the development of the offspring and for its nurture after birth; and interesting lights are shed on the intimacy of the ante-natal partnership, first by the discovery that there is a passage of regulatory hormones from the mother to the unborn offspring; and next by that of a passage of hormones from the offspring to the mother, and contributing to her health. Is not this a literal symbiosis, correcting the ugly old idea of "the fœtal parasite"?

There are many members, yet but one body; and, as St. Paul went on to say, "there should be no schism in the body, but the members should have the same care one for another." The body is regulated by its parts, and these are harmonised, even orchestrated; and all this we now call correlation. To the long-familiar correlation effected by the nervous system, and that also by the blood as the common medium, recent physiology has now added that by the hormones.

Illustrations from Ecology.—Gilbert White's letter on earthworms, written in 1777, was the precursor of Darwin's *Formation of Vegetable Mould*, published more than a hundred years afterwards; and central to them both is the idea of the correlation of organisms—the vital linkages that bind living creatures together in mutual dependence and interaction. This idea is an outstanding feature of present-day ecology. Nothing lives or dies to itself. As John Locke said, everything is a retainer to some other part of Nature. The earthworms plough the fields; the bees and flowers fit each other as hand and glove; the missel-thrush plants the mistletoe; the minnow nurses the mussel;

the water-wagtail helps the sheep-farmer; and the squirrel helps in making the harvest a success.

The inter-dependence of flowers and the insect-visitors that effect their cross-pollination is so striking, both as a general proposition and in its detailed nuances, that it could not but set people thinking and still searching for more. Again practical considerations, connected, for instance, with fisheries, have aroused interest in " nutritive chains "—such as diatom, infusorian, copepod crustacean and mackerel; and such studies continue to spread in widening circles. Another chapter of ecology has been the tracking of the life-histories of troublesome parasites; as lately with Liston in India practically solving the mystery of the guinea-worms—Moses' " fiery serpents " — and again with Rennie and White's discovery of the cause of the " Isle-of-Wight Disease," so fatal to hive-bees, in a mite infesting their breathing-tubes. Again, since malaria organisms and mosquitoes are co-operative, and minnows destructive of the latter, we are encouraged to look for other important linkages. Thus such studies are conspicuous in modern ecology. The answers to the more or less familiar riddles like those of squirrel, wagtail, and minnow may be found elsewhere, *e.g.* in Thomson's *The Wonder of Life*, but three or more new life-stories may be told.

The swollen leaves of a Leguminous tree

in British Guiana are tenanted by small beetles. They have established an alimentary partnership with minute "mealy-bugs" (Coccid insects) which share their shelter, eat its soft tissue, and yield a honey-dew—exuded in response to thirsty claims on the part of the beetles, both adults and larvæ practising urgent massage upon their insect-kine. Tree, bug, beetle—a threefold linkage; and sometimes ants take the place of the beetles.

There is a common tree-ant in Java—that land of wonders—which tolerates a hungry caterpillar as an inmate of the nest. The caterpillars, perhaps a dozen in a nest, do considerable harm, for they eat the cocoons of their host; and, unlike some other guests of ants, they yield neither pleasant fragrance nor narcotic exudation. Why then should such voracious guests be tolerated when they could be eliminated in an hour? Kemner, the Dutch naturalist who studied this interesting case, discovered that the silk-spinning activities of the caterpillars, when they are about to wrap themselves up before metamorphosis, are utilised for strengthening the leaf-walls of the nest. In spite of the toll taken by the grub-eating caterpillars, it pays to shelter them, and those nests are most successful that have their walls well strengthened with silken sheets.

One other kindred example. The larvæ of the death-watch beetle bore in wood or other dry materials, and the poorness of such food, in contrast to the plumpness of the grub, has often been the subject of remark. But it has been shown by Buchner that at the beginning of the digestive part of the food-canal there are two minute pockets crammed with yeast-plants. These bring about the fermentation of the dry-as-dust food, so that the death-watch larva is not so ascetic as it seems. There are many other cases now known where insects are such peripatetic breweries, and in almost all of these the eggs are found to contain yeasts from the very start. In the case of the death-watch, however, Buchner found that there were no yeast-cells in the egg, though the grubs have them in abundance. His explanation of this puzzle illustrates the subtlety to which linkages may attain. For he finds, associated with the egg-laying apparatus of the beetle, two minute reservoirs full of yeast-plants, and opening to the exterior. When an egg is laid, some yeast-plants are simultaneously expelled, and they adhere to the roughnesses of the chitinous egg-shell. When the beetle-grub is ready to be hatched, it makes its way out by nibbling at the egg-shell, and thus becomes provided with an initial supply of yeast-cells. Thus "a little leaven goes a long way" with the death-watch; indeed longest of all.

These examples—which could easily be multiplied tenfold—are not mere curiosities of Natural History, they are vivid illustrations of a widespread tendency in Animate Nature —to link lives together. It is a pleasant characteristic of modern ecology that there has been an eager pursuit of this kind of inquiry—which is, after all, but a continuation of Darwin's good old story of "*Cats and Clover.*"

It is necessary, however, to attempt a classification. (A) There are internal partnerships of physiological advantage on both sides. This is symbiosis in the strict sense, as illustrated by the algoid and fungoid partners that together make a lichen, or by the minute greenish algæ (*e.g.* Zoochlorella) that live inside the Radiolarians of the open sea, the green fresh-water sponge, the green Hydra, the green sea-anemones, many corals, and the Planarian Convoluta of the Roscoff sands.

(B) There are internal associations where there is marked benefit to the host, but less advantage to the other organism, which is sometimes only sheltered, sometimes also fed. Thus there are yeasts in many insects, bacteria in some, infusorians in others. The last may be illustrated by the extraordinarily beautiful and intricate Infusorians that are found in the food-canal of wood-eating white ants (termites).

(C) In a third set of cases the benefit conferred on the host is problematical. Thus there is strong evidence that in some luminescent animals, such as certain cuttlefish, the light is produced, not by a rapid fermentation as part of the animal's metabolism (as in the fire-fly), but by crowded nests of luminescent bacteria, like those seen on the glistening surface of herrings hung up to dry.

(D) Fourthly there is positive parasitism, where the benefit is more or less exclusively one-sided. It should be noted, however, that in many, if not most cases, some give-and-take compromise is also established, so that the host is not so much the worse. Rapidly fatal parasitisms are usually due to the parasite's invasion of a new host that has no counteractive defence. But the term parasitism has been used to cover a great variety of relations, and requires analysis. There is ecto-parasitism, as of lice, and endo-parasitism, as of worms; there is parasitism throughout the parasite's life or only for a period; there is parasitism confined to the female and correlated with securing the safety and nourishment of the young; there is alimentary parasitism where the parasite feeds on the food of its host; there is tissue-parasitism where the parasite, such as a bladder-worm or a Trichina, lying passive in muscle, depends on the nutritive material supplied by the blood; and finally, there is aggressive parasitism, when the parasite attacks the living cells of its host. It might be clearer, indeed, to remove from the ranks of parasites cases like the fleas of mammals, like ichneumon grubs eating out the interior of a caterpillar, or Trypanosomes destroying man's red blood-corpuscles; these are beasts of prey, without degeneracy, that devour their victim from within instead of from without.

(E) A separate place must be found here for relations that probably began as parasitisms, but have been regularised, like some disease-processes, and made useful to the host. The bacteria that form root-tubercles on leguminous plants, were they not parasites to begin with, though they have risen to the rank of symbions, enabling the plant to capture the nitrogen of the air, and thus blossom so profusely, seed so nutritively, as the leguminous plant does? Or, again, how is it that the heather flourishes so well on mountain and moorland where few other plants can survive? Its success is due to its close association with a thread-like mould, which inter-penetrates the whole plant, from root to stem, into every leaf, even into the flower and its seed. It looks much like any disease-causing mould; but in some subtle way it makes it possible for the heather to make a living on very unready soil, where water is not very available, even when abundant. Has not a parasite here been converted into a partner? A somewhat kindred story, though less extreme, might also be told of orchids, where the mould-partnerships are essential to germination, and thus make cultivation, formerly so difficult, a far easier matter.

(F) On a different line is Commensalism, a mutually beneficial *external* partnership between two quite different organisms, *e.g.* hermit-crab and sea-anemone. The crustacean is masked by its partner, who is likewise able to sting. The benefit to the anemone is that it is carried about by its bearer, and gets crumbs from the hermit's frequent meals.

(G) Somewhat simpler are cases where one organism grows on another without doing it any appreciable harm or good, but gains for itself some shelter or means of locomotion, some protection or strategic position. Epiphytes, such as orchids, gain great advantage from their perches on the upper branches of the trees of the crowded forest; and the sucking-fish (Remora) profits by being carried about by the shark or turtle to which it may fasten itself. Another fish, Fierasfer, insinuates itself, tail foremost, into the hind gut of a holothurian (sea-cucumber), where it finds the active respiratory water-circulation of great assistance for its own breathing. For if the holothurian be placed in foul water the Fierasfer comes out of its shelter, and rises to the surface, taking mouthfuls of air.

(H) It is not possible to draw a hard and fast line between such shelter-associations and a more or less fortuitous epiphytic or epizoic habit. There is probably little significance in the presence of a unicellular green alga on the shaggy hairs of the tree-sloth in the Brazilian forest; or in the anchoring of numerous acorn-shells on the carapace of a crab; or in the attachment of a bunch of ship-barnacles on the flattened tail of a sea-snake. At some new crisis, however, in the struggle for existence, what was indifferent may become vital, indeed of direct survival value.

(I) On yet another line of evolution are discontinuous partnerships, which are sometimes established between quite different organisms. Perhaps they may be ranked as discontinuous commensalisms. Thus various kinds of ants have useful associates, such as aphids, etc., with their honey-dew, besides guests, especially small beetles, some with palatable exudations, others with fragrance, suspected as narcotic, and some as yet unexplained, unless as mere pets.

(J) Then there are, on many levels, both gregarious and social, associations of members of the same kindred—in flock and pack, in termitary, ant-hill and bee-hive, in rookery and beaver-village. As a fine instance of ecology on this plane we may mention Prof. W. M. Wheeler's *Social Life among the Insects* (1924).

(K) Lastly come inter-relations on the largest scale—the mutual dependence of flowers and their insect visitors, the rôle of bird and beast in the distribution of seeds, and many other linkages that make Animate Nature a living system. We have outlined this series of correlations because their study is characteristic of the time, and also because they open up a line of thought of great importance for practice and theory alike.

CHAPTER IV

ILLUSTRATIONS FROM PALEONTOLOGY, EMBRYOLOGY, AND EVOLUTION

Illustrations from Paleontology.—The older paleontologists were mainly concerned with deciphering the succession of types in different geological ages, but the Cuvierian school especially undertook the comparative anatomy (and thus taxonomy) of fossil forms, whence ever-increasing attempts have been made to bring the extinct and the extant into line. But under the growing influence of evolutionist ideas, paleontography began to disclose phyletic and even genetic series, and thus became Paleontology proper. These series are rarely in any directly linear descent, but more frequently show a succession of grades, increasing in their characteristic differentiation, or it may be simplification of parts. A good example of such general grading is afforded by the pedigree of the horse type, so well established from toes to teeth. A more definitely linear succession—for a short range—is beautifully illustrated by Hilgendorf's famous series of Württemberg water-snails. Millions of their fossil shells were found in Miocene sands at Steinheim, disposed in successive strata and horizons. The lowest of these was marked by *Planorbis steinheimensis ;* the next contains the closely related *Carinifex tenuis ;* then follows *Carinifex multiformis*, with its numerous varieties, which, however, arrange into one almost continuous series, of about eleven steps, each but a shade different from the other, yet in which the beginning, the middle and the end might well be of different species, if not even different genera. This series, well called *multiformis*, begins with the flat Planorbis-like disc of the variety *discoidea ;* it ends with the top-like variety *trochiformis.* This great variability has been referred to the influence of over-flowing hot springs in the vicinity; but that does not lessen the suggestiveness of the transformation that certainly occurred. Modern research has been rewarded by the discovery of many other of these clear phyletic series. In such cases the long lamented " imperfection of the geological record " is being got over.

Distinctively modern paleontology may well be dated from the work of Woldemar Kowalevsky (1874), a Russian evolutionist of distinction, who devoted himself to the study of fossil Ungulates. The step he took (not without precursors, as usual) was that of attempting a much more ambitious reconstruction of the past. He tried to relate his fossils not only to extinct ancestors and extant descendants, but to their habits and to their environment, both climatic and animate. Kowalevsky's name is still unfamiliar except among kindred experts, but he was the initiator of biological and ecological paleontology—working, gradually of course, towards clearer phylogeny. In speaking of his monograph on the fossil Ungulates, Osborn—perhaps our best living American authority—writes: "It regards the fossil not as a petrified skeleton, but as moving and feeding; every joint and facet has a meaning, each cusp a certain significance. Rising to the philosophy of the matter, it brings the mechanical perfection and adaptiveness of different types into relation with environment, the change of herbage, the introduction of grasses. It speculates upon the cause of the rise, spread and extinction of each animal group. In other words, the fossil quadrupeds are treated biologically, so far as is possible in the obscurity of the past." As prominent continuers of this Kowalevsky tradition may be mentioned Osborn himself and his colleague Matthew, Lull of Yale, Dollo of Brussels, and Abel of Vienna; while the American Museum of Natural History in New York is the finest of its expositions as yet.

Since Huxley's day the fossil horse has been "the *cheval de bataille*" of the evolutionist; yet the story of the elephant, worked out by Andrews, Matthew and others, is not less impressively complete. Millions of years ago, in the Eocene epoch, when there was warm and moist climate with luxuriant grassy vegetation in many parts of the world, there lived in North Africa a primitive hoofed animal called Mœritherium. It was about the size of a small donkey, and apparently had a short snout, suited for gripping the herbage. It had the second incisors on the upper and lower jaw alike enlarged into small tusks; the back teeth were transversely ridged; and the bones of the skull were beginning to be lightened by the formation of air-cavities. Such was the ancestor of the elephants!

Ages passed, and in the Lower Oligocene there emerged a larger creature, Palæomastodon, standing 4–6 feet high. The snout had lengthened—and was now a strange combination of the nose with part of the upper lip—Nature's way of making a novelty out of something very old. The nasal opening on the skull was further back than in Mœritherium; the canine teeth had disappeared and also the incisors, except the two pairs of tusks; the grinding molars were larger and bore three transverse ridges. There were more air-cells in the skull-bones—in short Palæomastodon was much nearer the elephant of to-day.

There is a gap in the rock record through the Upper Oligocene, but in the Miocene there appeared Tetrabelodon, as large as a medium-sized elephant. The nasal openings on the skull are even further back; the upper tusks have grown stronger; the grinding teeth have more ridges; the skull has more air-cells. It is probable that the end of the snout had become gradually longer and more mobile. In the earlier species of Tetrabelodon the lower jaw was elongated in front, thus forming a bony support for the snout, and they had tusks suited for grubbing in the earth. But as the Proboscidian head became larger the neck had to become shorter so as more easily to carry it; and this eventually implied that the head could not be bent far down. Thus in the later species of Tetrabelodon the lower jaw was shortened and could no longer reach the ground, while the snout, now freed from its bony support, had to grow into a long and flexible proboscis.

Ages again passed; for it was not until the Pliocene that there appeared the genus Elephas, mammoths and elephants proper. Yet these are in some way linked back to the Miocene Tetrabelodon by the well-known genus Mastodon. In Elephas the shortening of the chin has continued; the lower tusks have disappeared; the back teeth are now huge grinding-stones, further strengthened by more numerous and complicated transverse ridges of enamel. The upper tusks have grown longer and stronger, and the trunk longer too. To support the elephant's great tusks and gigantic molars, the skull had to become enormous; and this was also of service in affording insertion-surface for the strengthening muscles of the trunk—able now to lift a fair-sized fallen tree. But the increased development of huge air-cavities in the skull-bones counteracted the tendency to an over-increase in weight. Improvements thus continued—and all in correlation.

Illustrations from Embryology.—The development of the chick from the egg remains a perennial wonder, and we must still confess with Harvey (1651) that "neither the schools of physicians, nor Aristotle's discerning brain, have disclosed the manner how the cock and his seed doth mint and coin the chicken out of the egg." The first problem is to describe the succession of events in the everyday epiphany of life, and this description continues, of type after type, partly for the intrinsic interest of each, and partly with the hope of making some discovery that will illumine the process of development as a whole. Thus descriptive embryography seeks to lay the foundations of rational embryology.

Of recent pieces of descriptive work there is none finer than Johann Schmidt's account of the life-history of the common eel. When the eels of our ponds and slow-flowing rivers become full-grown—the males at 4–6 years old, the females 5–7—they become restless. The reproductive organs are beginning to ripen; the composition of the blood is modified, containing more carbon dioxide than usual; subtle structural and functional changes appear in the body, such as the apparent enlargement of the eye, and an alteration in the shape of the snout, and of the colour towards yellow. The eels leave the pond and make for the river, indeed sometimes squirming through a meadow to find it; they descend by night in excited crowds, and pass out to sea. But the whole sea is not suited to supply the liberating stimulus which brings on spawning; only certain waters will serve. Thus from the North Sea, which is not deep enough nor warm enough, the eels migrate to the open Atlantic; and it is only after eighteen years of wide and patient tow-netting that Schmidt has been able to prove that the main spawning-ground is an area between 22° and 30° North latitude, and about 48° and 65° West longitude, nearer in fact to the Bermudas than to Britain.

The newly-liberated eggs have not been found, nor yet developing ones; but it is probable that the actual spawning occurs in deepish (" bathy-pelagic ") water. The transparent larvæ, 2 mm. long, swim gently near the surface, and feed on microscopic organisms. Every stage is known from these very young larvæ to the full-grown eels.

Months pass, and the minute larva begins to be more active. It is knife-blade-like, as clear as glass, without any spot of colour except in the eye. It is still called " Leptocephalus "—the first name given long ago to the first stray specimens, when their nature as larval eels was still unsuspected; but now it is known as " glass-eel." More and more, as they grow, they become swimmers rather than drifters; thus, in oceanographic terms, passing from the floating surface medley of " Plankton " into the active ranks of " Nekton." They are now beginning to migrate from their birthplace, and through new seas towards the coasts. An interesting point is that the spawning area of the European eel overlaps that of its close American ally; and while the young of the latter swim westward, those of the former head for the east. Dr. Wemyss Fulton has suggested that this overlapping of the spawning grounds of these species may be reminiscent of the time when the two species were one, and when the New World and the Old were nearer one another than now. For according to Wegener's theory of the drift of continents over a less rigid substratum—like enormous icebergs moving slowly on the sea—America was once in touch with Europe, but has moved westwards at a faster rate. Be this as it may, there can be little doubt as to the common origin of American and European eels, and the interesting question arises, How is it that the American larvæ now move westwards and the European larvæ eastwards? The biologist who regards the organism as a historic being, which has the past registered in its constitution, will answer that there are slight differences in the "reaction-systems" of the two species and slight differences in the stimuli to west and east in the sea. Thus the larvæ answer back differently.

But a more concrete consideration is this. The two species differ in relatively trivial ways, such as the presence of an extra vertebra in the American form, but they differ more radically in the length of their larval period, thus illustrating what may be called "time-variation." In the precocious American species the larval period lasts a year; but in the slower European species two years and a half. If European larvæ were to swim westwards, *as some possibly do*, and thus, with much the shorter journey before them, they would reach the American shore too soon, before they were developed enough to ascend its rivers. Again, if the American species swam eastwards—as some may mistakenly do—they would complete their metamorphosis too soon, long before they were near the European coasts. Thus in the course of time there would be, as in other migrating animals, a natural elimination of types that did not react suitably.

To return to our glass-eels making definitely for Europe in their slow way. They continue to grow slowly for a couple of years and more, and become as long as the large blade of a schoolboy's pocket knife. In their third year they are approaching the European coasts; and then they begin to undergo metamorphosis. They cease to eat; they change their shape from knife-blade-like to cylindrical; they cease to be translucent and begin to develop pigment. At this stage they are about the length of one's first finger and the thickness of a knitting-needle. In a word they are now our familiar "elvers."

From the coastal waters the elvers make their way up the streams, often in a dense crowd known as an "eel-fare." They hug the banks, avoiding the full force of the current, and their inborn prompting to go straight ahead, no matter what obstacles there may be, is very persistent during daylight hours. Whenever the sun goes down, however, they snuggle under stones or beneath the bank, and wait for morning. They do not dart about like other fishes, but exhibit to the observer and experimenter an interesting "tropism," *i.e.* an ingrained obligatory movement, which automatically adjusts their body so that the pressure of the current is reduced to the same minimum on each side. Thus if they should be borne obliquely outwards by the entrance of a tributary, there is an immediate adjustment so that they again head up-stream. They also tend to regain the water near the banks where the pressure of the current on the whole tends to be least. The strength of the impulse to go straight on may be gauged from the persistent efforts they make to circumvent a waterfall by clambering up the wet moss on the rocky sides. They may even make short excursions in the moist grass. Another interesting detail is that the dates of the eel-fare (usually a Spring event) in different rivers correspond with the distance the elvers have to travel along the coasts before they find an appropriate river. Thus the ascent of the Aberdeenshire Dee may take place a month after the eel-fare in the Severn. Why the elvers should persist in exploring rivers so distant as those of the Baltic—involving a journey of over two thousand miles—is beyond present-day science.

What can one say save that it illustrates the insurgence of life? There is no way of proving the guess that the elvers of the Severn and the Dee are the offspring of the adult eels that left these same rivers four years previously! Here it may be noted that the adult eels of both sexes seem to die after reproducing, a signal instance of death as the tax on the abundant production of life. It is certain that adult eels never return from sea to rivers; and it is also certain, in spite of persistent statements to the contrary, that eels never spawn in fresh-water.

Schmidt's triumphs have thus been three: the discovery of the main breeding ground of the European eel, the description of every stage of development from the very young larva of two millimetres to the adult of two feet, and his tracking of the migration from mid-Atlantic to the rivers. There is nothing better in the whole literature of embryography.

But the embryographer becomes, even in spite of himself, an embryologist; thus, behind the former's beautiful descriptions of individual Becoming, there is a growing recognition of the organism as a historical being which enregisters past experience in a living way within itself. What, then, is the true inwardness of this extraordinary migration from river to sea in maturity, and from sea to river in youth? There is strong probability in the view that the common eel is a scion of a deep-sea race, which has taken to colonising the fresh-waters. Many of the eel-tribe are permanently abyssal; the common eel is a roving adventurer that has found his Eldorado in the rivers. Explain it who will, many animals return to their birthplace to breed—thus the land-crabs from the palm-groves to the salt shore, and the turtles from the open sea to the sands: and, best of all, the migrant birds from their winter-quarters in the tropics to their nesting-places in the far north. The eel's migration is another of these cases, and an extreme one, in that it returns to the birthplace to die! From such instances we begin to see how present ontogeny and past race-history may illuminate each other. There are many parallel cases; for while experts dispute whether the salmon is a marine fish that has taken secondarily to the rivers, or a fresh-water fish that has taken secondarily to the sea, everyone admits that the flounder is a marine fish that is nowadays in many places consistently exploring the streams, and is thus sometimes caught a good many miles beyond salt water. But markedly fluviatile as it often is, the flounder must return to the sea to spawn; and there also its offspring must spend their early life. The ways of living beings thus often repeat those of their ancestral history.

Illustrations from Experimental Embryology.—Beyond the description of the successive phases in any life-history the deeper questions arise: How come these phases, and how is it that stage B emerges from A, and C from B? After von Baer, Haeckel most elaborated the answer that organisms are historic beings, in which much of their ancestral past lives on; and hence the succession of their developmental stages is to be interpreted as a more or less condensed recapitulation of great steps in their racial history. This recapitulation indeed was Haeckel's "fundamental genetic law"; and it has been widely recognised and ably illustrated: yet, it must be confessed, somewhat exaggerated too.

Other embryologists, notably Professors His and Rauber, initiated a then quite new physiology of development. They asked: What are the dynamics of the changes by which the cells of one segmenting ovum form a ball and those of another a disc? How is it that the hollow ball (blastula) common to many types is pushed in, so as to form a two-layered sac (gastrula)? Again, they asked for, and even attempted, a mechanical explanation of the longitudinal (mid-dorsal) folding that forms the "primitive groove" which becomes the central nervous system of the Vertebrate embryo. And what intelligible forces separate off the embryonic axis (notochord) from the roof of the primitive gut? How do those various pouchings of the food-canal arise, that later become lungs, liver, pancreas and other organs?

These two ways of looking at development, the recapitulatory and the dynamic, seemed at first contradictory, whence controversies accordingly: but, as so often, it became evident that these two viewpoints are complementary. The first laid emphasis on the ancestral inheritance, and strove to decipher the long historical recapitulation, and to investigate the material ways in which the lineage is somehow concentrated. The other lays emphasis on the immediate physiology and dynamics of each development. The working out of the "Recapitulation Theory" is the older of the two, the outcome of fertile initiatives by von Baer, Haeckel and Fritz Müller. The physiological enquiry is mainly post-Darwinian, and most notably expressed in the work of Roux, who gave it the name "Entwicklungsmechanik"—the mechanics of development, without thereby claiming to give fully mechanical description of all its processes.

Of this modern movement in experimental embryology a good illustration may be found in the attempts to understand what occurs in fertilisation, the pre-condition of ordinary development. In several starfish and sea-urchins, some worms and molluscs, and even in the frog, it proves possible to bring about artificial parthenogenesis. That is to say, an egg-cell which normally requires to be fertilised by a sperm-cell may be launched on aspermic development. Delage's best method with sea-urchin eggs was the addition of tannin and ammonia to the sea-water in which the eggs were floating. This mixture set the eggs developing, and then they were replaced in ordinary sea-water. Delage succeeded in rearing a fatherless sea-urchin to an age of three years, and this as normal as viable.

Another discoverer of artificial parthenogenesis was the late Prof. Loeb, one of the most ingenious of biological experimenters. He subjected the eggs of sea-urchins and starfishes to the influence of butyric acid for a very short time. The fatty acid set the eggs developing; they were then shifted to sea-water rather denser than usual (hypertonic), and this kept them on lines of safety—from dividing too quickly, in fact. Finally, they were restored to ordinary sea-water, where they developed normally. There are yet other ways of inducing aspermic development, but in every case there seem to be two main factors. First, the new stimulus which activates the egg, perhaps positively, or by removing some restraint. But the unaccustomed stimulus may be too energetic, and even lead to disintegration (cytolysis). Hence the need of the second factor—some counteractive, such as restoration to ordinary sea-water, which serves as a life-saving brake.

Most striking of all is Bataillon's method of securing the parthenogenetic development of frog's eggs. He places the frog's spawn on a board, in conditions where the presence of spermatozoa is impossible, and pricks the eggs with a fine needle of glass or platinum; he then washes them with blood (which need not be that of a frog). The eggs are then restored to normal conditions and a large percentage develop. The pricking with the needle starts development; but the cell-divisions would proceed with fatal rapidity did not the entrance of a blood-corpuscle serve as a corrective. The development is quite normal, and several fatherless frogs—of both sexes—have been successfully reared.

After the egg-cell has begun to divide, the experimentalist may intervene, and disturb the normal arrangements and sequences. Some of the results are more curious than instructive, but others are very suggestive. When part of the cell-substance of the ovum of a Ctenophore or of an Ascidian is removed without injuring the nucleus, the cleavage may be peculiar, and the embryo defective in some precise way. This suggests that in such eggs there are definite organ-forming substances which are located in particular areas. In some other cases, however, *e.g.* sea-urchin, an excised fraction of the egg-cell may be fertilised, and may develop into a normal larva; which points to the conclusion that some kinds of ova are the same all through (equipotential), and that a part may thus be as good as the whole. Perhaps the most striking case of this development of fragments ("merogony") is that reported by Delage, that less than a twentieth of a sea-urchin's egg—and without any nucleus—was fertilised by a spermatozoon and gave rise to a complete larva. This points to the important conclusion, confirmed in other ways (*e.g.* by parthenogenesis), that the egg-cell and the sperm-cell have each of them a complete endowment of hereditary characters.

It comes to this, that some egg-cells are very homogeneous, while others are heterogeneous, with a mosaic of building materials which can form certain structures, but not others. The manifold proof of this is recent; but the idea goes back to His, who elaborated in 1874 a theory of "organogenetic germinal areas," in which he pictured the egg-cell as a mosaic of diverse materials. Modern work has added the complementary idea of different rates of metabolism in different areas of the egg. This suggests a cross-reference to some recent work on sex-determination. Thus Riddle maintains that pigeons have two kinds of eggs, differing in storage metabolism, one female-producing, the other male-producing. (See *Sex* in this series.)

A neat experiment subjects developing eggs to gentle shaking. Thus Prof. E. B. Wilson of Columbia separated the first two cells of the lancelet's ovum and obtained from each a normal embryo, which grew as far as a half-sized larva. He had thus coerced the egg-cell into twinning. When the shaking of the water, in which the eggs were floating, was even gentler, the first two segmentation cells were incompletely separated; and now double-embryos—like Siamese twins—resulted; which developed to double-larvæ, surviving for a day. Complete isolation of the first four cells yielded four embryos; incomplete separation yielded quadruple-embryos and other strange results. But units from the eight-cell stage, though able to move about actively, did not develop. This indicates that division of labour begins to set in at that stage, and that the individual units then lose the power of forming a complete embryo.

It is instructive to contrast the developing egg of the frog with that of the lancelet. When Roux punctured one of the first two cleavage cells with an electric needle, and kept the egg fixed, he found that the remaining intact cell developed into a one-sided half-embryo. At a certain stage, this regenerated the missing half; and usually by re-vitalising the remains of the cell that had been punctured. But when Hertwig made the same experiment of pricking one of the first two cells, he obtained a complete embryo of half the normal size—an interesting discrepancy in the results of two equally-skilled experimenters. It was then pointed out by T. H. Morgan that if the ova are kept stationary after the operation the result observed by Roux is likely to be seen, while if the ova are allowed free movement, or are shaken about in the water, a readjustment of material is effected, and what Hertwig observed is likely to occur. This case gives a glimpse of the subtlety of the conditions that influence development.

One of the outstanding results of experiments on developing eggs is a demonstration of "regulative capacity"—an ability to set things right when they have been coerced into going wrong. An egg may be whirled round, and its living substance thus so far disarranged that the segmentation becomes of unusual type; yet a normal embryo may be developed. Similarly, when the egg has developed as far as a ball of cells, these may be badly disarranged; and yet without ending in abnormality. This was one of the facts that led Driesch to sharpen the antithesis between the organism and a machine.

We have seen the developing embryo to be delicately susceptible to external influences, especially those of chemical reagents; yet in other ways it shows impressive toughness. It is often striking in its return to normality; it has some self-stabilising power, as it were a gyroscope within. But what is this that can stabilise the disturbed embryo, and bring it back to the straight path?

At any rate the organism's development shows processes of regulative control. There seems to be an organic inertia, and an ultra-microscopic architecture, a stereochemical specificity, like that of a crystal. The dynamic aspect of this is to be sought in the steady stream and concatenation of distinctive chemical processes, though the components of this organic momentum are not yet known. Something definite, however, has been discovered in regard to the influence that one part of a developing organism has upon another. There are startling experiments on this embryonic correlation of parts. Thus in the early development of the Vertebrate eye, the first step is a club-shaped outgrowth from the brain, which pushes out till it comes into touch with the embryonic epidermis, below which it now hollows into a cup, the future retina. This contact induces division and thickening in the epidermis, which soon becomes the lens. It has been shown by Werber and others that if the optic club of an early tadpole be broken into several parts, each may induce the formation of a minute lens. Furthermore, a fragment of optic club may be surgically implanted on another tadpole, even in some quite irrelevant place, such as the side of the body, and will still provoke the formation of a lens! Some specific ferment-like influence may be imagined to pass from the nervous tissue of the optic club to the epidermic cells.

Another example of the control that one part may exert on another is to be found in any growing shoot. The growing point is the region with the highest rate of metabolism, and there is a gradual decrease down the stem. Within a variable distance from the growing point a sway is exerted over the buds; they cannot develop until the tip of the stem has grown to some distance away from them. If the growing point is covered with a small cap of plaster of Paris, it loses its "physiological dominance," and the buds which were inhibited will begin to develop. If the plaster cap be removed, the development of the buds will stop and the young shoots will die. But if the lateral shoots developing from the buds had been able to outstrip the apex of the stem before the cap was removed, then the inhibiting power of their growing points will predominate over that of the apical shoot, which will therefore die.

While the regulated inertia of the developing embryo is characteristic, one must also recognise a frequently delicate susceptibility to chemical reagents. It seems that alterations in the position and arrangement of cells can be readily adjusted, provided that they are not associated with some drastic chemical disturbance that upsets the usual routine, like a poison in adult life. Thus Dr. E. I. Werber subjected the developing eggs of the American minnow (Fundulus) to various reagents, especially butyric acid; and thus provoked all sorts of monstrosities, in eyes and ears, nostrils and mouth, fins and heart. The butyric acid seems to disarrange, and partly dissolve, the essential germinal material, especially towards the head end; hence monstrosities. It is interesting to note that when the metabolism of carbohydrates goes wrong in a mammal's body, one of the results of the disturbance is the production of butyric acid. But if a mammalian mother's constitution were thus poisoned by the production of butyric acid, that might be the cause of monstrosities in the embryo: a fresh light on a very old problem.

This instance of the dissolving and dislocating of germinal material prompts enquiry into those cases where it is *normal* for one ovum to give rise to many embryos (polyembryony). Thus the Texas armadillo has normally quadruplet embryos, all from one ovum, and all therefore of the same sex, like "identical twins."

Illustrations from Evolution.—There are three fundamental problems before the student of organic evolution: (1) the nature and origin of variations; (2) the conditions of their hereditary transmission; and (3) the scope of the various processes of sifting and pruning that go on in Nature. We shall begin with variability.

Variability.—The past living on in the present is what we mean by heredity. There is a continuance of specific characters from generation to generation. Men do not gather grapes of thorns or figs of thistles. All kinds of characters, important and trivial, normal and abnormal, of mind as well as body, *may* be continued in the inheritance. Even a character like longevity may be handed on, or an unimportant peculiarity like style of handwriting. Fertility and some measure of infertility are hereditary, until, indeed, the latter comes to an end in organisms that are sterile. In short, like tends to beget like; and the reason for this is to be found in the fact of germinal continuity which was emphasised by Galton and Weismann. At an early stage in the development of the animal embryo, the future reproductive cells are often distinguishable from those which are forming the body.

The latter exhibit division of labour and become muscular, nervous, glandular, skeletal, and other cells, thus losing their likeness to the fertilised ovum of which they are the lineal descendants. But while this is going on, the future reproductive cells, taking no share in body-making, remain virtually unchanged and continue the protoplasmic tradition intact. Thus they are able by and by to give rise to an offspring, which will resemble the parent because it is made of the same protoplasmic material, and also because it develops under more or less similar conditions. Thus, in a sense—as Galton first remarked and as Weismann more fully explained—the child is as old as the parent. It is indeed a chip of the old block. In plants, however, the distinction between body-cells and germ-cells is not sharply drawn; everyone knows how a fragment of a leaf or shoot may develop into a perfect whole. There is a persistence of embryonic material in many parts of plants, and this may carry the inheritance as completely as do the special reproductive cells of fern or flower.

But like only *tends* to beget like, for variability is well-nigh as much a fact of life as the continuance of hereditary resemblance. The relation of organic continuity between successive generations—heredity, in the strictest sense—has thus to include the possibility of something new. The vehicles of the hereditary characters are the germ-cells, whose intricate processes of maturation and fertilisation afford manifold opportunity for new permutations and combinations. In the preparation for, and at the beginning of each new life there is an elaborate shuffling of the hereditary cards, and this results in each young offspring having its own particular " hand." A character may drop out, the animal may grow up a pigmentless albino, like a white rat or a white blackbird. Or the offspring may inherit some strong feature, for better or for worse, from both sides of the house, so receiving what is technically, though not very elegantly, called a " double dose " of that character. Again, the characters of the two parents may be combined into some new pattern, the extreme instance of which is a piebald pony. Or a character from one parent may be dominant over a corresponding, but different, character from the other parent, so that the latter remains latent (recessive) in the offspring—though likely to reassert itself in a certain proportion (about a fourth) of the grand-offspring.

Most striking, and most puzzling, are those variations which are not readily interpreted as " a little more of this and a little less of that," since distinctively *new*—qualitative novelties rather than quantitative. Thus a variety of the Greater Celandine with cut-up leaves appeared without warning in 1590 in an apothecary's garden in Heidelberg, and it has been breeding true ever since. In 1886, the Dutch botanist De Vries found in a potato-patch near Hilversum a sporting variety of Lamarck's Evening Primrose, in which "the mood was all mutation." It was a wild species in North America in the eighteenth century, and thence taken to Europe, where De Vries found it displaying extraordinary mutability. It produced numerous offspring very unlike itself, some of them ephemeral failures, but others viable and breeding true—just like species in the making. Here are indeed very striking "sports," yet of such mutations of species there are scores. Thus the pomace-fly (Drosophila) in America has given rise to almost as many mutants as the Evening Primrose. There are mutations among rats and among potato-beetles, among birds and butterflies—in most groups, indeed, where careful search has been made; and these are illustrated in mankind in such brusque yet heritable novelties as brachydactylism ("fingers all thumbs"); or again, on the psychological side, as a calculating boy or a musical genius.

However we may look for variability, from smallest fluctuations to greatest mutations, we find them throughout animated nature, except in those conservative types that have settled down with a very stable constitution in surroundings marked by persistent uniformity. These prove but exceptions, for the rule is change. In short, then, it is characteristic of living creatures to give rise to offspring which are in some respects new. Of the sources of this flow of novelties, biology has, as yet, little secure knowledge; but there is no doubt as to the abundance of the supply. And it is in these variations and mutations, which well forth from the germinal fountain, that biologists are seeking the primal impulses of evolution.

Another feature of organisms is their "modifiability"; for this is often of great importance in the individual lifetime. There is a capacity for adjustment which finds little counterpart among not-living things. The animal's skin thickens protectively under repeated pressures; the plant's epidermis thickens in course of drought. The fleece becomes thicker and longer in cold surroundings, and the leaf of a plant shifted from the low ground to the mountain may become more densely hairy. The Herring Gull—which too often feeds in summer on grain and other crops in the farmer's fields—acquires a more gizzard-like stomach than that appropriate to its normal diet of fish. To the strain of unusual activity an animal may respond by increased muscular development, and this in heart as well as limb. There are hundreds of these adjustments, and although there is little evidence in favour of the view that they can be in any direct way entailed on the offspring, they may be of great, even life-saving, value to the individual. Indirectly, moreover, they may count in racial evolution, for every character of an adult organism is a product of the hereditary nature and the environing nurture. But our present point is simply that among the characteristics of life must be included not only germinal variability, which leads on to improved adaptations and new species, but also the capacity for individual adjustment to environment and function, and this even for their peculiarities of detail.

Heredity.—The re-discovery and development of Mendel's principles of heredity has made a radical change in the whole field of genetics. It has been shown that many an organism consists, in part at least, of a great bundle of "unit characters," which behave in inheritance as if they were indivisible entities, like the radicals or the atoms in old-fashioned chemistry. These unit characters do not blend or intergrade; they are present in a certain proportion of the descendants; they are either there in their entirety, or completely absent; but it is now known that they may be in some degree masked in their developmental expression by other characters or by environmental conditions. Unit characters may be illustrated by eye-colour, which never seems to blend; by "night-blindness" or inability to see in dim light, which has persisted in the Nougaret lineage since Charles I was king; by the "Hapsburg lip" so long noticeable in the royal houses of Austria and Spain; and by brachydactylism, which means having only two joints in the fingers.

To illustrate the heterogeneity of Mendelian unit characters, we may continue the list for a short distance among plants and animals. It includes yellow seeds in peas, immunity to rust in wheat, six-rowed ears in barley, early ripening in various cereals, serrated margins in nettle leaves. It includes hornlessness in cattle, crests in poultry, Angora hair in rabbits, albinism and waltzing in mice, pink eye in fruit-flies, broodiness in poultry, colour-bands on the shells of wood-snails. The list of *demonstrated* unit characters is increasing very rapidly, and some biologists have gone the length of predicting that all the components of an organism's inheritance will be found to belong to this category.

We may refer to Prof. MacBride's *Heredity* in this series for a discussion of Mendelian inheritance; so only the briefest note is needed here. If a Japanese waltzing mouse, with its constitutional peculiarity of dancing round and round on the slightest provocation, is crossed with a normal mouse, all the offspring are normal. This is technically described by saying that the waltzing character is recessive, while normality is dominant. But no one yet knows why one character should be dominant and its analogous counterpart recessive; no prophecy can be made beforehand.

When the hybrid mice, apparently quite normal, are inbred, their offspring will consist of about 25 per cent. of pure waltzers, and 75 of normals. If these waltzers of the second filial generation are bred with others like themselves they produce pure waltzers exclusively. If the normals of the same second filial generation are inbred, or paired with others of similar history, a third of them will produce pure normals, while the other two-thirds will produce normals and waltzers in the previous 3 : 1 ratio. This is the Mendelian rule, of which Mendel gave an ingenious explanation. Before stating this, however, let us mention half-a-dozen examples of characters that show Mendelian inheritance, placing the dominant first in each case: hornlessness and the presence of horns in cattle; normal hair and long angora hair in rabbits and guinea-pigs; crest and no crest in poultry; bandless shells and banded shells in the wood-snail; tallness and dwarfness in peas; susceptibility to rust and immunity to the disease in wheat.

The theory that Mendel suggested in explanation of his rule is simple enough. At the beginning of each individual life, when the egg-cell is fertilised, the same number of chromosomes is usually contributed by each parent. If one of the parents has a dominant character, *e.g.* a tendency to early cataract—which the other parent has not, the unfortunate probability is that the offspring will show the dominant character. According to Mendel this offspring will produce in equal numbers two kinds of germ-cells, one contingent with, and the other contingent without, the factor or "gene" for the dominant character. If the said offspring should marry another with similar history, the likelihood is that three-fourths of the grandchildren (the second filial) will show the tendency to early cataract.

The central idea is that of the segregation of the factors for the dominant and recessive characters into two equal contingents of germ-cells, one with the dominant character and the other with the recessive; or one with a dominant character and the other with nothing corresponding to it. If eggs and sperms from the two contingents come together in chance distribution the Mendelian ratios must occur.

It may be that some of the more ancient and stable components of an inheritance have their vehicle in the cytoplasm of the germ-cells; and of the egg-cell in particular, as is suggested by experiments already referred to, which show that the removal of a particular portion of an ovum is followed by a particular defect in the embryo. But it has been proved that the germinal "representatives" of many of the more variable and less ancient characters are carried by the nuclear rodlets or chromosomes.

These germinal representatives are technically called "factors," or "genes"; and T. H. Morgan has found objective basis for the view that they lie in linear order in the chromosomes. It seems practically certain that particular chromosomes, as in the fruit-fly Drosophila, carry the factors of particular characters, but Morgan has ventured further than this, even to indicating what region of a particular chromosome is occupied by a particular factor!

The Mendelism of to-day is not quite so

hard and fast as that of twenty years ago. Thus it is admitted by some that one " factor " may occasionally affect several different characters in the adult. That which expresses itself as a " white eye " sport in Drosophila seems at the same time to affect the insect's productivity. Conversely, a particular character may be the product of many factors. Thus Morgan and his collaborators have found in Drosophila 50 different factors that affect eye-colour, 15 that affect body-colour, and 10 for length of wing. There seem to be eight factors co-operating to produce the complex coloration of a wild rabbit's fur; and the simplified colours of domesticated rabbits, *e.g.* white, black, yellow, and grey, depend on the number of the factors that have dropped out of the inheritance in the different breeds. When there is unrestricted crossing of breeds, a restoration of the original complex must come about, and the wild rabbit's fur is restored—a result which used to be mistakenly interpreted as a " reversion."

The Mendelians of to-day show an abandonment of an earlier somewhat " portmanteau-ish " view of inheritance, since now willing to allow that one factor may influence another. Thus a Drosophila fly with the factors for vermilion eyes cannot be distinguished from one with the factors for pink eyes, if both contain, in addition, the factors for white eyes, for the factors for white eyes allow no other colour to develop. That the factor for pink or for vermilion eyes may be carried by a race with white eyes is readily proved by crossing with flies that are not white, for the pink or the vermilion will crop up in a certain proportion of the offspring.

It is also recognised that a specific environment is often required, if a particular factor is to find expression. The offspring of a race of fruit-flies marked by an abnormal abdomen will appear perfectly normal if raised in a dry bottle; but the presence of the factor for abnormal growth may be demonstrated by rearing their offspring in a wet bottle! There is a stock of Drosophila marked in winter by a considerable percentage of individuals with supernumerary legs; yet there are few or none in summer, especially in warm weather. Miss Hoge found, however, that if the summer flies were kept in an ice chest at a temperature of about 10° C., a high percentage had extra legs.

Selection.—Central to Darwin's thinking, as we have seen, was the idea of the manifold inter-relations of living creatures in the web of life. His vivid picture of this made his appreciation of the processes of Natural Selection far more subtle than that of some of his exponents. But the progress of Ecology, which we have already illustrated, is disclosing more and more of the complexity of the web's pattern, and has made it easier to understand how nuances of variation may be tested in the struggle for existence. Natural Selection can distinguish between a shibboleth and a sibboleth, *e.g.* between two bees that differ in the length of their tongue, or in the number of hairs on their pollen-basket.

There is an escape from false simplicity in the idea of an evolution of natural sieves, as well as of the variations that are sifted. In different geological ages, in different types, and at different periods of life, the selection differs in its emphasis. Fundamental always is the quest for food, and also the parrying of the thrusts of changeful physical forces; but we must think also of the sieve of the animate environment, *e.g.* of neighbours, partners, and parasites. In some cases the animal society or the herd acts as the sieve, and it is quite plain that temperamental pre-dispositions may be the subject of selection within, just as much as armour and weapons for use without. Survival rewards the parentally careful birds, as surely as the invulnerable tortoises, or the poisonous snakes. In some cases the ægis of the social organisation, *e.g.* in ants, allows of variational experiments that could not be more than transient among animals living singly. To take an extreme case, there are slave-owning ants which cannot feed themselves even when food is abundant; and in ants, bees, and wasps we are familiar with a worker-caste practically sterile.

Another important idea is that the inter-linking of lives tends to prevent retrogression. Thus the mutual dependence of flowers and their insect-visitors will work against any change on either side that would be prejudicial to the long-established inter-relation.

The larger the number of linkages an organism has, the less likely is it to suffer retrogression, provided always that it does not become parasitic. The social corollary for mankind seems clear.

Continuing the Darwinian tradition, many biologists of to-day have insisted on the variety of selective processes. There is, for instance, lethal selection, which prunes off the variants in the direction of relative unfitness. There is reproductive selection, which operates through the increased fertility of the fittest. Thus to make a fine lawn one may persistently eliminate the weeds; or one may use a differential fertiliser that promotes the multiplication of the grass only. Another modern step is the actual demonstration of the efficacy of selective processes; as shown, for instance, in Weldon's observations on crabs, or Poulton's on caterpillars, where the elimination was shown to be not at random, but quite definite, working towards the survival of variants in a particular direction. Take a diagrammatic case. Cesnola tethered brown Mantises on withered herbage, where they escaped the eyes of hungry birds; and green ones on green plants, with the same result: whereas brown insects on a green background, or green insects on brown, were soon picked. This was an experiment, but it goes far to prove that in an arid country the brown variety of Mantis would survive, while in a country with luxuriant vegetation the survivors would be green. It is useful to keep in mind Punnett's calculation that "if a population contains ·001 per cent. of a new variety, and if that variety has even a 5 per cent. selection advantage over the original form, the latter will almost completely disappear in less than a hundred generations."

In recent years critics of Darwinism have made much of the fact that selection fails to effect progress in a "pure line," *i.e.* among the inbred descendants of an individual or of a pair. Thus Johannsen has shown that if the descendants of an individual bean seed of high-class parentage be kept apart, no amount of selection will get beyond the mean of the line. There is, indeed, an appearance of "fluctuations," such as taller plants and shorter plants, but if the talls are selected out and bred from, there is no establishment of a tall race; and the same holds true for the shorts. There is nothing to choose between the descendants of the talls and the descendants of the shorts. The reason for this is probably that the "fluctuations" that occur in the pure line are not "germinal variations," but individually acquired peculiarities or "modifications," due to slight differences in the soil or exposure. If this be so, we cannot assume their heritability, which is certain for many germinal variations; and it is plainly useless to try to select from among the possessors of non-heritable characters.

But there are other reasons why we should not allow these pure-line experiments to hurry us into a depreciation of the rôle of selection in natural wild conditions, where, as a matter of fact, its operations are sometimes demonstrable. Two considerations may be submitted. (1) Pure lines are not typical of wild stocks, in which cross-fertilisation is frequent and consequent germinal variations are common. (2) It is dangerous to argue from brief experiments to the age-long processes of Nature. Although heritable variations, or mutations, did not occur in Johannsen's pure-line beans, it is premature to exclude the possibility. If one did occur, it might be utilised as the starting-point of a new advance. We conclude that the pure-line experiments need not lead us to doubt the validity of evolving Darwinism. All that they show is that in various inbred races, whether of beans or guinea-pigs, a *ne plus ultra* may be reached as regards certain characters—a limit beyond which no amount of selection effects any permanent change. Against this we have to balance other facts, such as Castle's experiments with "hooded rats." For in one and the same stock he selected simultaneously in two opposite directions as regards colour, and succeeded in producing two very different races, one almost quite black, the other almost white.

CHAPTER V

BIOLOGY IN ITS LARGE ASPECTS

The Institute of Biology.—Here then, and in more or less fresh and alike general and special ways, we have seen there are great unities running throughout the sciences. And if so, the preceding method of biological bibliography—sub-classified, and historically progressive and cumulative—is manifestly as adaptable to each and all of these as to our own immediate use: and with like working convenience, simplicity and mastery. For precursors, editor-initiators, continuators, with commentators, and expositors too, are as plainly recognisable in one science as in another. That this method is a labour-saving device for the intensive specialist, and yet more for the ambitiously comprehensive con-specialist, within his own science, or even on his entry into sciences beyond, is manifest in theory, and also workable in practice; though, of course, for its particulars the admirable labours of our historians of science, such as Dr. Singer in London and Dr. Sarton with his "Isis" in Harvard, must be utilised, and extended to the full. As our historic grasp of the progress of the sciences thus advances, and this at once in the concrete and in the abstract together, we shall learn more and more fully to widen our interests beyond our immediate fields. For the library shelvings of each of the other sciences may now also be as clearly constructed, at any rate in working model, as card-catalogue, since these, each and all, will be seen to have an essentially similar pattern for their essential literature, in its historic development and progress.

Return a moment to our essential planning. That is, not simply as of outline card-catalogues and book-cases, but as a vivid way of visualising the progress and process of each and all the sub-sciences, by help of the three categories of space, energy and time. Our previous diagram, its charting of the sub-sciences, has been but a Mercator-like projection, made by help of these three taken together upon the flat surface of our paper: but now we may better visualise these categories, as the three essential intersecting planes of a sphere. For now we have its eight segments more clear than ever, since seen as the inevitable octants of our apple of knowledge. The reader will indeed find it wholesome thus to cut his next apple—once through its equator, and twice vertically through its poles—and visualise its significance and comprehensiveness as he consumes it, part by part; and all this still more clearly if he explains as well as shares these with his Eve-Egeria.

Reverse now this shrinking process. Return from this condensed knowledge-apple to our card-catalogue, even our great bookcase room for our science: and now expand this last in turn. Dream this indeed, as rising, spreading, even into the vastest of buildings, many-storeyed in modern American fashion, and with elevators at call, up and down throughout. Our four-columned schema now adorns—and with pictorial friezes—the sides of its lofty and colossal central and common hall. Group-studies are thus provided for along its higher galleries, and individual analytic studies upon its lower ones: while each and all of these galleries has its own perspective outlook, back into the hall of unity. These also open into the respective laboratories, museums, collections and workshops, of all the world's workers in every one of biology's attractive fields. For each and all of these many wings and storeys of our edifice has been built from and for Nature without, and so must keep its outward views and communications fully open; for we are still, and more than ever, nature-students. It is the central Hall of Unity which is the last to be reached and viewed. Indeed each storey, as aforesaid, has still but its own perspective of this: only when we can fully pass on all sides, up, down, and round, can the whole unity become visible, and this no mind has therefore fully seen. Yet many have glimpsed it, all may who will.

And when we have glimpsed this, our vast dream-Palace of the Life-Science is next seen to shrink, and shrink again—at length into a tiny sphere—the unit-cell of knowledge, yet packed with all its heredities: for it is now the microcosm of mind, within the Macrocosm of Nature. Yet again this process reverses: for the human Mind is ever extending anew, and cannot cease to grow, towards that ever-fuller ensphering of Nature, which is the aim of science.

Final Rationale of Main Arrangement.—But the questions may—and indeed must—be asked: (1) Admitting all these sub-sciences as having arisen naturally enough from experience, and thence rationally also, why not more? And (2) how justify this particular grouping of them?

The phenomena studied by biology, like those of every other science, are conditioned by space: so what we have first been considering has been the ways of studying our organic forms, analysing individual forms as far as may be, and thus step by step downwards in our schema (*i.e.* through organs, tissues, cells, protoplasm), and also synthetising (classifying), step by step upwards, *i.e.* through varieties, species, genera, etc., to the Organisata, the whole "biosphere." Thus in diagram we have

(Forms, as to) *Space*	Synthetised	↑	Groups
	Analysed	↓	Individuals

But next our organic forms are of interest to us not primarily as dead, but as living; an essential distinction! In physical terms, our biologic studies may view them statically in the museum or upon the dissecting-table: —hence, were this all, we should have but four necrographies, or "pure morphology" at most. But as biologists proper, we view them above all kinetically, in the field or the aquarium, *i.e.* with their living energies, each a going concern (and this on each and all the levels of our ascending and descending series of enquiries). Thus, for energy aspects,

(Forms, as to) *Energy*	Static	Kinetic

Hence our studies of forms dead (or viewed independently of their life-activities) are all static, and from the first on the (passive) left hand; and those of forms in living activities are kinetic, on the (active) right.

Finally (for science knows of no fourth category in this series), we cannot but view our organic beings, in their forms and functions alike, in time: but this is past, present, or possible. Both forms and functionings are manifest in the present; but past groups, and past individual phases too, are done with; and hence are both now on the static side. But whatever developments are possible must be functional, in life. Our Time diagram is therefore—

(Forms as to) *Time*	Past	Present	Possible

So now superpose the three preceding diagrams, since all life's phenomena are conditioned by the triad—space, energy, time. The diagram is exactly that of our eight sciences—

We have now but to insert the above terms in the fields of the sub-sciences they define: thus we have—

Groups Static Past (*Paleontography*)	Groups Static Present (*Taxonomy*)	Groups Kinetic Present (*Ecology*)	Groups Kinetic Possible (*Phylogeny*)
Individuals Static (Phases) Past (*Embryography*)	Individuals Static Present (*Anatomy*)	Individuals Kinetic Present (*Physiology*)	Individuals) Kinetic Possible (*Ontogeny*)

It thus plainly appears that this eight-fold schema—since of space, energy, time—is necessarily of equally general application to all the phenomena we can find in the universe: so that the astronomer's nebulæ and stars, suns and planets, satellites or meteorites, must thus be considered, and indeed actually are so; and so for the geologist, with his rocks and minerals in form and change, as a little reflection will show. Physicist and chemist too are playing essentially the same intellectual game as the morphologists and physiologists above. For their analysis first reached molecules and atoms, and is now applied to these in turn. Note too the chemist's "graphic formulæ" (as of "benzol rings" and what not), and now even models of atomic structure, morphological and also comparative, as are our plant-diagrams (say) of bud, bulb and flower; and also kinetic, indeed evolutionary, in their own way.

Thus, though these fellow-searchers have not yet used our above method and nomenclature, it is mainly because of their keen bustle of research, and each mostly along his own special shelves, that they have not arrived, and long before us, at this essential classification of the sub-sciences of any and every phenomenal science. Yet partly because, as above pointed out *re* Linnæus, biology is the classificatory science par excellence. In short, then, here we claim for it that all bibliographies of the sciences are thus fully parallelised.

These principles of sub-classification have clearly their appeal to the mathematician; from whom indeed we take them. For though, *as such*, he has not the concepts of matter and energy, of organic form and function, nor of social filiation, yet his familiarity with form in space, and with movement in time, must yet prepare him for the fullest

NOTE ON DIAGRAM II.

A. Beginning at the lowest corner to the left, we represent mathematics by axes in three dimensions. Logic, as another methodological science, is indicated by the tri-dimensional swirl.

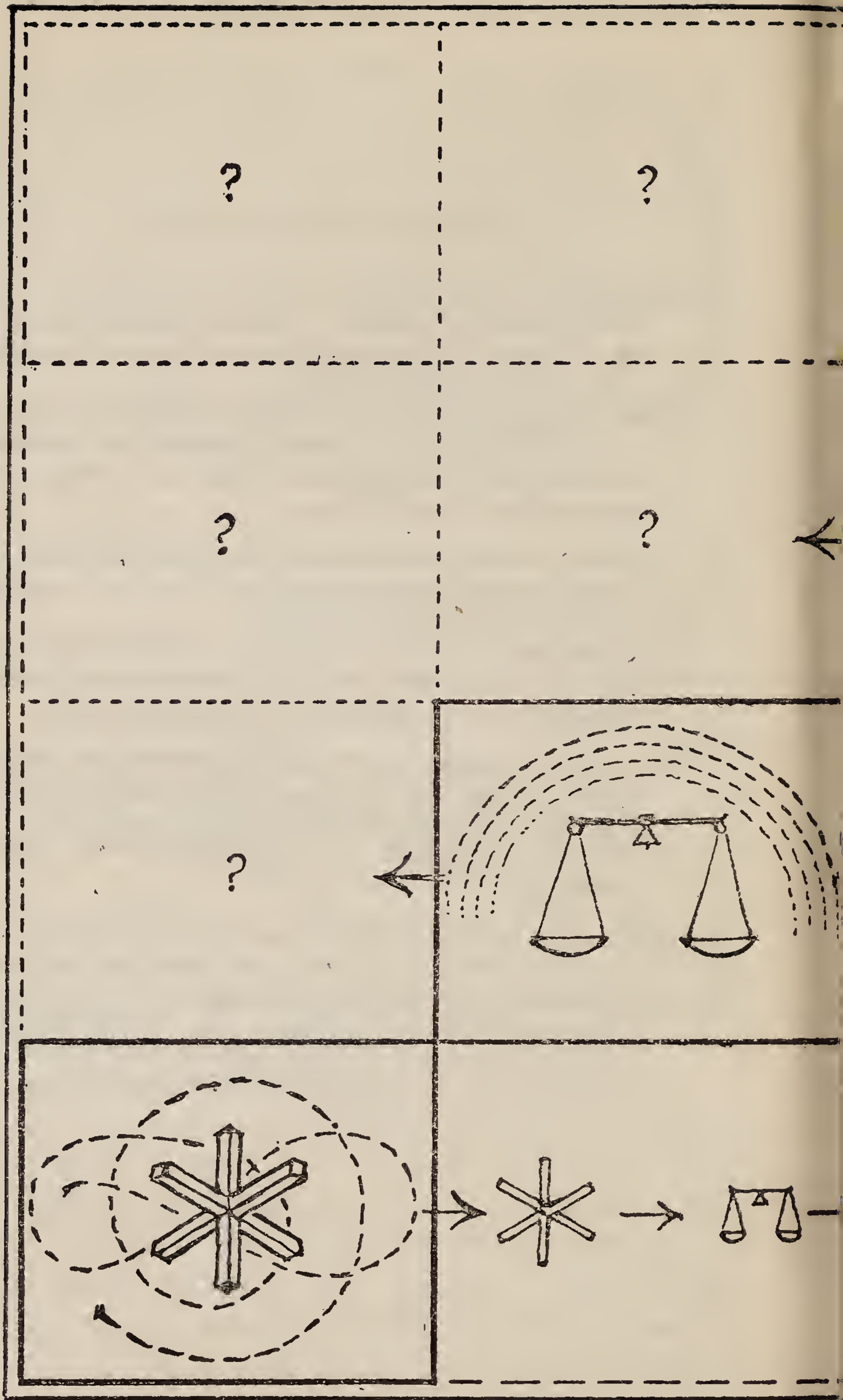
The compartments to the right indicate successively the applications of mathematics to physics (the balance), to organisms (the scarabee), and to sociology (the book).

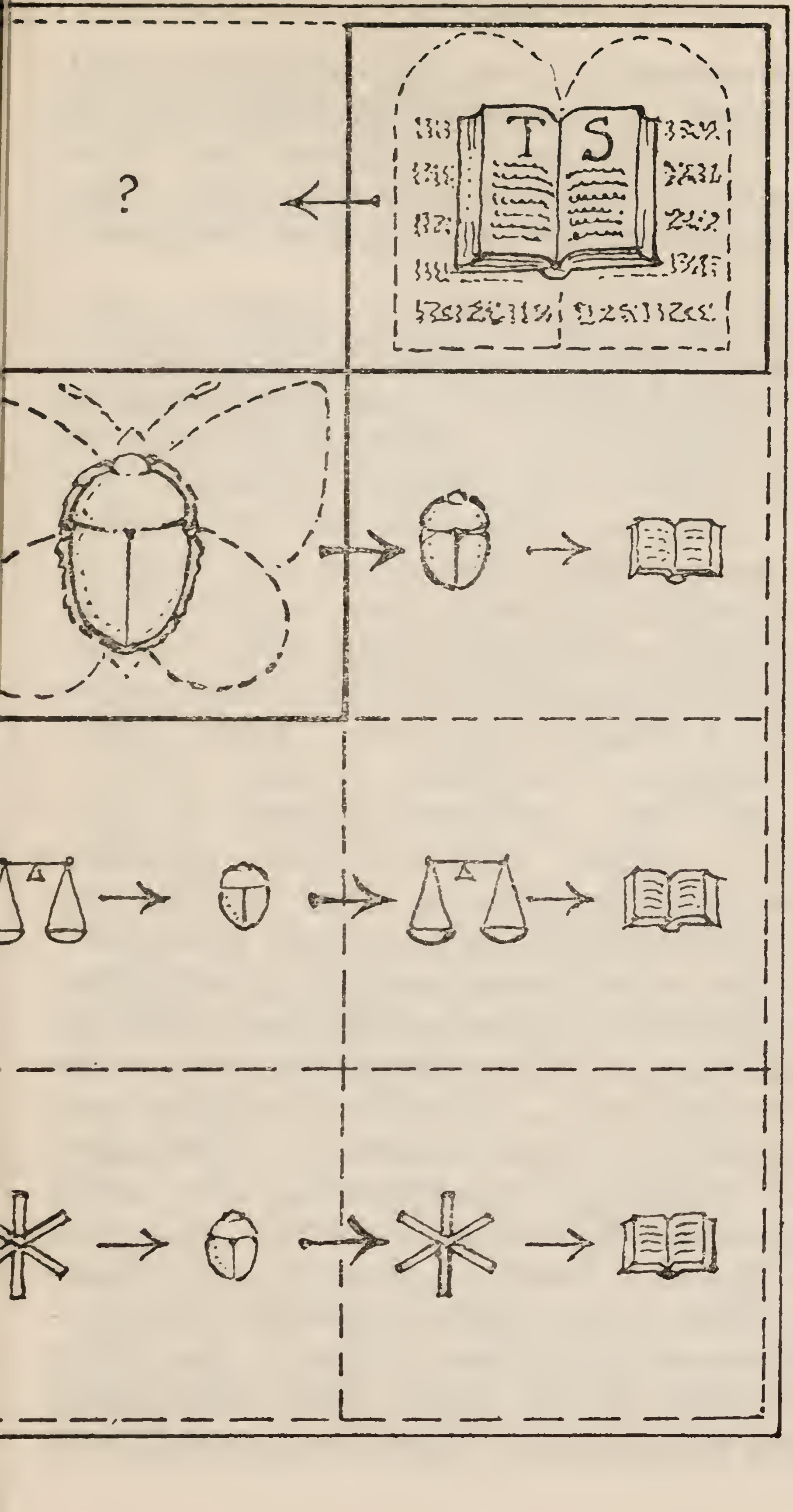
B. The left rectangle on the second level indicates physico-chemical science, symbolised by the balance. The rainbow stands for esthetics.

The compartments to the right indicate successively the applications of physico-chemical science to biology (the scarabee) and to sociology.

C. The left rectangle on the third level indicates Biology (symbolised by the scarabee), inseparable from Psychology (symbolised by the butterfly). To the left is suggested the application of biology to sociology.

D. Highest is indicated the place of Sociology (symbolised by the book with its temporal and spiritual records). And, as Logic with Mathematics, as Esthetics with Physico-chemical science, as Psychology with Biology, so here Ethics, symbolised by the Tables of the Law, is associated with Sociology.

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of all masteries of our Life-including triad. Here indeed is inexhaustible scope for his nimble mind at play throughout the whole range of the phenomenal universe; thus becoming seen as Cosmos, and by him above us all.

Surely now our scheme must be, for biological purposes, in principle completed ?—since comprehensive for the phenomena of organic nature, as manifested in form, in function, and in the passage of time. Yet behold, a long line of philosophers, undeniably evolutionary, from Heraclitus to Bergson, appears and confronts us; since entering with the opposite perspective, and with broadly generalised idea, and watchwords, from "*πάντα ῥεῖ*"—"All things flow," to "Elan Vital" and Evolution Créatrice. Among them—indeed, for once at least, clearest of all—hearken to Hegel, with his great formula: "Becoming, Being, Having Been." This way of looking at life is indeed now that of advancing biology, which is emancipating itself from its own historic origins, which have hitherto been guiding our scheme-building, yet, as we now see, limiting it. For this is of the very essence of the current concrete evolutionary way of thinking, re-interpreting the older Ecology and Physiology for their emergent types: for it is from all this dynamic functioning that evolutionists now strive to interpret structure and form, alike in its living present, and in its past. Our historically arranged schema must thus be reversed, and with advantage, as now in the order of life's own history; hence as—

$$\frac{\text{Phylogeny}}{\text{Ontogeny}}\ \frac{\text{Ecology}}{\text{Physiology}} \rightarrow \vdots\ \frac{\text{Taxonomy}}{\text{Anatomy}}\ \frac{\text{Paleontology}}{\text{Embryology}}.$$

Our science thus presented, in this evolutionary-dynamic order, is freed from its initially empiric necro-graphy, and is now fully bio-logic at last. Indeed may not this rational ideal of advancing Biology be condensedly viewed thus?—

BIOLOGY {	PHYLOGENY (with *Paleontology*)	⇄	ECOLOGY (with *Taxonomy*)
	.↑.↓.	LIFE	. . . . ↓↑
	ONTOGENY (with *Embryology*)	⇄	PHYSIOLOGY (with *Anatomy*) }

After all, these two apparently fresh presentments of the sub-sciences offer no real difficulty—least of all when we accustom ourselves to see these as octants of biologisphere—for both are already clearly manifest upon our apple of knowledge,

BIOLOGY IN RELATION TO HUMANISTIC STUDIES.—So far, then, for the general scope and vision of Biology, in its sub-sciences and as a whole. Enough, too, for their justification in method, applicable in other sciences of Nature. But more than half our colleagues in the vast modern University of Universities, of which our edifice is but the Biological

Institute, are not biologists almost at all, nor much at home in these kindred institutes of other sciences with which we increasingly have dealings. Theirs are " the humanities," as they used to call them (indeed still do, in Scotland especially). What, then, are these? Languages, dead and living, with their Literatures correspondingly, Histories, ancient and modern, at once invite and perplex us: for here are specialisms even more numerous than in the sciences, so that few have ever mastered much of many, and no man all. Here, too, are vast Philosophies, each claiming to be synthetic, yet different, even divergent, since from so many ages, lands, and minds; and, beside these, moral philosophies perplexingly distinctive, however fundamentally kindred; Psychologies yet less reconciled; and doctrines of Esthetics as yet well-nigh irreconcilable. Or are we of more concrete minds? Here are Political Economists in abundance, whole Schools indeed, but at fundamental variance among themselves or with others, and thus naturally the Political Philosophers can have no more single light. We hear the Logician proclaiming his subject as " the science of all sciences, the art of all arts"; as indeed it deeply is: yet few men of science get much help from him, nor will, until he comes to meet them, and towards full co-operation. Thus John Stuart Mill's " Logic," well-wrought though it was, and in some respects beyond the old way—thanks in part to his recreative pursuit of gathering a good herbarium, both of the British flora and the richer French one—did not lead him (as his and every other "Logic" claims it should) to add any appreciable point to his science, or even to ask a fresh question within its field. Indeed, has this vast literature of Logic, despite all fair promises, been thus really stimulating and helpful to the sciences? Its arrests, as to Greek sophistry, and in course of medieval scholasticism, certainly bulk more largely. May not—must not—the needed rejuvenescence of logic require all and more than such endeavours as we are making here, to carry on our sciences and our logic together, consistently con-specialised, and no longer, as heretofore, all but dis-specialised? Hence, indeed, Bio-logy, as ideal. Thus when Mill came beyond pure Logic to Socio-logy, as in his later works, he had something worth while to say.

Many at least of the preceding wide range of humanistic outlooks are practicable, even necessary, from our subject of Biology, itself in Evolution, and thence capable of reaching increased comprehensiveness. For all their labyrinths of studies are so many records of the voicings and doings of our highest species; and nothing now living, or once living, can be foreign to us, as students of Life. But can we see order amid this labyrinth where lifelong dwellers and searchers fail? Yes; even make some order, anew; in time reorganise; where need be replace, re-build. Why should, how can, the classificatory and evolutionary sciences shrink from bringing in their potent methods here?

We must at least try our keys of biology upon the doors of these innumerable departments, though so often firmly locked, even against each other. What,—our now comparatively small eight-warded key, for its own specialistic sub-sciences, of which most humanists scarce know the names? Surely, yes: for what is our "Paleontography" but the projection of their "History," their "Archæology"; now deepened for man, and extended to other life-forms as well? What are our "Embryographies" but preliminaries towards their "Biographies"? What is our "Taxonomy" but the life-wide extension of their "Ethnography," from "Shem, Ham, and Japheth" onwards? What their Anthropography (up to their portraits and statues even) but our "Anatomy" in the making? Their "Economics" is our "Ecology"; and its details, as of occupation, of division of labour, etc., answer to our functional studies, our "Physiology." But what of our Evolution studies, our "Phylogeny," for instance? What but the extension throughout Nature (and by and by again to Man himself) of their venerable, though still discordant, Philosophies of History? See, too, their unending tasks of Criticism, of individual developments and careers; and those throughout all their fields of study, historic, literary, philosophic, and the rest. These discussions are of "Ontogenies," of interest beyond others, and attempts to rationalise them beyond mere descriptive, "embryographic" facts. Thus, may be now parallelised both fields, the humanistic with the naturalistic, since alike conditioned within space, energy and time.

"History" & "Archæology."	Ethnography.	Economics (& Politics).	Phil. of History.
Paleontography.	*Taxonomy.*	*Ecology.*	*Phylogeny.*
Embryography.	*Anatomy.*	*Physiology.*	*Ontogeny.*
Biography.	Anthropography.	Economics (detailed).	Biography (critical).

It must be here noted that the above schema by no means claims to include all humanistic studies, but strictly those of clear biological parallelism, in nature and in origins, in (mutual) impulse, and interest. Thus, Philosophy, so far as beyond the scope of science, and similarly Religion, and Art, are not included here; save for such specific sociological, and even biological, interests as they may present. To locate and more fully to relate these great fields, we have still to look deeper into their origins, in life.

Here, in fact, is a first broad parallelism of Biology, and its sub-sciences, with what we must now call Sociology, with its sub-sciences so essentially akin.

This diagram suggests the possibilities of Biology towards aiding the complexer human studies, throughout its simpler yet underlying parallelisms to those of social life. But it also serves to express, and to acknowledge, the deeply humanistic origins of biological studies themselves. For though Sociology has been latest in origin as a specific science, there is another aspect, in which the order of origin of the sciences is seen in the very reverse order from its usual historical perspective—mathematical, physical, biological and social. For when did people not talk of their affairs, past, present and possible? How else could language have been developed? Affairs of food-supply, and of family, of disease, etc., were thus the primal stuff of biologic arts and sciences: and so were the handling of materials, tools and weapons for their physical congeners: while social needs of numbering, and by and by measuring, in time initiated the mathematical group. In those simple old days of early man, unformed though must have been his specific concepts of arts and sciences, he must thus have had their elemental synthesis, in his everyday working life, and in his leisure too. It is long since civilisations lost this unity; and thus themselves: so now, in the modern Babylons which are our great cities, the renewed Babels which are their towering universities and schools of learning, we seem further from unity than ever, as War and after-War have so much shown. Yet the converse movement—towards recovering unity in thought, and this towards action—has also long been in progress, albeit too little recognised: so let us see if this unity cannot be made clearer, throughout the sciences; and in each perspective of them. But this needs a fresh chapter.

CHAPTER VI

THE CHARTING OF THE SCIENCES

Is it asked—Why trouble about the other sciences? Why not stick to biology, which is what really interests us here? Because even from our earliest nature-studies, and yet more from the three preceding chapters, we have seen life as conditioned on the great scale of inorganic nature; as astronomically, by the seasons, and geographically, topographically, climatically too: and we have to observe life's adaptations on the small scale also, even to the finest details of soil-composition and chemistry, or those of moisture, light, temperature, and even of pressure. The mechanist, the physicist and the chemist moreover have each in turn—and now together more than ever—become our teachers; for without their searching explanations we could not understand the simplest workings of our own bodies, much less enter upon the innumerable intricacies of life's manifold functionings, its incessant—even Protean—change. For all these preliminary sciences, too, their master-thinker is increasingly the mathematician; and he even accompanies them into our biologic fields, as in exactly measuring the variations we had too vaguely observed, and calculating and graphing these, with precision, fertile in unexpected results.

Hence, without here recapitulating the long discussion of "the classification of the sciences," from Aristotle to Bacon, or through Comte and Spencer to Pearson, Naville and others, we shall understand our biology far more clearly, work in it more productively, even apply it more securely and fruitfully also, if we once broadly settle where we stand upon the long stair of intellectual climb—*scala intellectus*.

Start, then, with mathematics, as did the Greeks of old; for some comprehension of number and measure, some visualisation of points, lines, planes and solids, some reasoned handling of all these, has been undeniably fundamental for further intellectual education since Plato wrote over the gateway of his Academe its matriculation condition, "Let no one ignorant of geometry enter here." Yet though far greater attainments than Plato's can be (and are even being) utilised in biology, we ordinary workers need not go much beyond those taught in the more progressive schools.

But beyond the strict thought-range of pure mathematics—essentially dealing with space and number, movement, time—the human mind seeks for understanding of the phenomenal universe: and it seems first to have been deeply impressed by the sun's steady course from dawn to sunset, and by the moon, so strangely and variably contrasted, in light, in changing form, in seeming-erratic course. The stars too, with their fascinating brilliance, their steady course across the sky, have among them wanderers, *planets*, perplexing in their course as the moon herself. The sun is thus plainly All-father, on whom all life, for light and warmth, plainly depends; but the moon? With her rule of night after the day's labours, her strange periodicities too, she is surely woman-like; and somehow akin also to the very Earth-mother herself. And the planets, in their appearances and courses, why not for these some relation to the human events we may remember along with them—why not at length suspect their dominance, and even in time take this to be confirmed? In such ways astronomy and astrology could not but arise, and long advance together: and though wandering far beyond positive science, it was much for man thus to realise the dependence of life upon astronomic conditions, some of which we still go on investigating, as in solar physics.

For all this research, ancient and modern—observant, yet more and more speculative—the mathematician has increasingly been called in. Indeed his precise observations and calculations, even to prevision, as of eclipses especially, his changing interpretations, above all, make up the main history of astronomic science. Yet its biologic interest never fails:

witness, for instance, the long reluctance to abandon Ptolemy's stable geocentric system for the mere planetary rank, and whirling flight, to which the heliocentric doctrine committed us. Then too, when this shock to tradition had calmed, came those long questionings towards planetary life which have in our time been so stoutly maintained by Lowell for Mars. Witness too the speculations of Kelvin, and next of Arrhenius, as to different conceivable ways of diffusion of life's germs throughout space. Again the limitation, by Kelvin and others, of the age of the world; and thus for the origin and the continuance of life, even to stern renewal of the ancient terrors of life's ending upon our globe, if not perchance in the fiery mist of some solar collision, then inexorably in icy chilling under an increasingly exhausted sun. The reprieve since assured us by the chemico-physicists of radium is thus of fresh biological interest. The study of physical geography, with meteorology, climatology so plainly conditioning life, from snows to seas and sea-bottoms, is so obviously indispensable to the biologist as to need no illustration here: for masterworks, from Humboldt's "Cosmos" to Wallace's "Geographical Distribution" and its successors, with corresponding Atlases, valley-sections, sea-soundings, are plainly essential to our deepened taxonomy and ecology. The complemental study of geology, with its surveys and maps, general and local, has given us our paleontography, our thus-extended taxonomy, and has advanced phylogeny as well; as, for familiar example, the successively appearing five-, four- and three-toed horse tribe, which made our modern one-toed type "the battle-horse of the evolutionist." Conversely too, our ecology aids the geologist in appreciating the changing climates of his past; and his results react in turn.

Enough, however, of such illustrations from our nature-studies in the open to show how much inorganic nature-studies are needed for our understanding of plant, animal and human life: but when we come to physiology proper we have far more constantly to be applying all we can learn of mechanics, physics, chemistry; indeed we have to become as far as may be mechanicians, physicists and chemists ourselves, if we would really understand vital functionings at all. Thus vertebrate hearts are pumping-machines of increasing complexity, lungs are bellows: as for nerves, how better begin to explain them than by help of electric wires? even our spinal cord, with its "reflex actions," is made plainer from our telephone systems, through which "stimulus" evokes "response." Such simple mechanical and physical explanations are ever being carried farther. So much so indeed that it is no wonder the physical physiologist should ask, even challenge—Who can say how far? And who dare say "no farther!"?

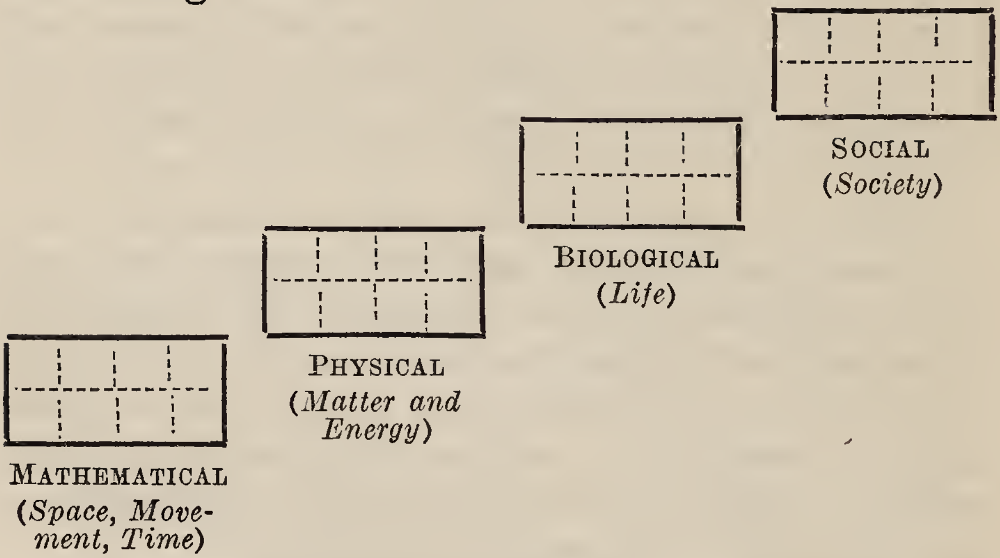
The like for the chemist's contributions to physiology; from his pioneering initiatives, like the epoch-making synthetic production of urea, to his further advances, as with sugars yesterday, adrenalin to-day, and proteins to-morrow. We have more and more to profit by his discoveries, and thus become at least students of bio-chemistry. Where indeed is there more fertile suggestiveness to continued progress, or past and present achievement more sparkling with interrogation-points towards the future?

Very encouraging also, since towards ever-increasing clearness, and for enquiry beyond mere statement, are the graphic notations, formulæ and methods of all preceding sciences. We have long had figures, and ever morphological diagrams: but we also need to give graphic forms to our more abstract ideas too; hence those of preceding chapters.

Their highest uses are not simply their comprehensive lucidity of summary; nor their biographic, historic and thus bibliographic aid; with their two-fold rational help to memory, even towards mastery. Their stimulating aid towards further enquiry is our main reason for pressing them, alike upon reader and investigator, as veritable "thinking-machines"—for thus we escape any mere mechanisation of thought, and acquire increasing thought-mastery of useful mechanism.

It is full time for biologists to be taking stock of the sciences, which are all of aid to them: so these may be first outlined in series.

The Mathematical and Physical (of course with Chemical) precede the Biological; since long recognised as necessary preliminaries to their adequate prosecution. Beyond biology too, we have had to make place for the social sciences. We must thus rank the sciences in an ascending series :—



Next let us (1) simplify the above, by omitting sub-divisions; yet also (2) associate these main sciences more clearly and definitely: using also symbols instead of words. For though—to our lifelong "print-habit"—graphics are at first unfamiliar, and may seem strange Hieroglyphics, their use is soon found convenient, even helpful in practice. For they are *Ideographs*, and indeed strangely like those with which script began and developed, as in Egypt and China, long before phonetic alphabets arose from them. Hence let us put down for Mathematics the intersecting Axes of geometry, so potently used by Descartes. For

Physical Sciences with their essential ideas of matter and energy, we may take Lavoisier's Scales, for the permanence of matter; and also, as oscillating Balance, expressive of the conservation of energy (and its dissipation too). For Biology, the beetle not only best expresses the protean variety of the forms of life, but also, as Scarabæus of antiquity, may stand for the deepest conceptions of life we can form. Finally as ideograph for Sociology, the Book may nowadays most simply express the social heritage. (See Diagram II.)

The Sciences De-liminated.—Here then stands our present series of four essential sciences, arranged in accordance with their historic origins. And this also in their ascending order, *i.e.* of concrete complexity and intellectual intricacy; with their increasing difficulty and incertitude accordingly, and these alike for understanding and for prevision. Note how the application of each science towards aiding and interpreting its successors is clearly provided for in each case; so that from an at first unstable, bending, or even breaking series, like a half-arch, the later diagram stands now like an architect's drawing for a clear-hewn and solidly-built step-way; indeed as a "leaping-on stone" for the Pegasus of thought. (See Diagram II.)

Yet we have seen, indeed from the outset, that the components of this (now 4 + 6) can be no mere whole and simple blocks. Each is a card block, *i.e.* a rational catalogue, for each and all the departments of its main science, and for those fundamental to it, and thus preliminary. We have therefore here before us in principle and outline, the specialised library of each science, and of its applications to those following above.

Our historic knowledge is thus growing. Our current interests are also more catholic; our outlooks bolder, since more clear. Our self-education in the sciences, with mutual education also, is thus progressing, and more rapidly as well as more fully. Here too comes in the usefulness of graphic methods; as by earliest geometers, and onwards to "Napier's bones," which came to life as logarithms, and have since been claimed, and truly, as "the most labour-saving of all inventions." This labour-saving by help of graphics is going on in every science; and we cannot but make like claim for this more comprehensive one, here before us. Recall the ancient dreams of sciences;—say first of *Lapis Philosophorum*—no mere alchemist's magic stone for mere material gold-making, but the secret of synthetic (thus so far philosophic) power. Indeed in its complex unity we may see its build, as in the structure and formation of a crystal. For do not our orderly catalogue cards somewhat in this way express the historic upbuilding of the sciences, and the process of their advance?

Returning to our diagram, and its main series in detail, we see how mathematics extends to underlie physics. Note next how the physical sciences advance and become fundamental to biology: and how this in turn is deeply needed by the social sciences; for, as Schiller put it—and not so much as poet, but from his medical education—"While philosophers are disputing about the government of the world, hunger and love are performing the task." Hence, too, Wallace's direct answer to the writer's question of "How did you come to the theory of Natural Selection?"—"Just like Darwin, by reading Malthus."

But now the physicist should also have contributions to aid the social studies; which indeed his epoch-making discoveries and their cognate inventions—so deeply transforming human society, and thence its outlooks—have largely evoked. Hitherto too little; since political economy soon fell back, from concrete interest in industrial advance, to studies of market values, in monetary terms, thus in principle logico-mathematical. But here came in Stanley Jevons, a mind with physical knowledge and insight, who startled his brother economists, renewing—for the coal-supplies of Britain as the essential energy sources of its industries—the very doctrine of "intrinsic value" they had dismissed; since—for money values—"What is worth in any thing, except so much as it will bring?" In this physicist's way he even shocked them further, by correlating commercial crises with sun-spots, through possible climatic changes affecting world-harvests. Such initiative long lacked continuation, yet this also is resuming progress.

In more recent times mathematics has come to aid biology, with its quantitative precision, thus bringing order into our observations, previously but qualitative, as of variations. Hence Galton, as brilliant initiator for more exact study of human life, was followed by continuators like Weldon, measuring variations in the common shore-crab; and both more fully by Pearson, with his "Galton Institute," his periodical *Biometrika*; while Davenport and others are no less productive. Such contributions of mathematical thought to biology have also been largely stimulated from its epoch-making applications, more than a generation earlier, to social facts and changes by Quetelet, essential editor-initiator of modern "Statistics": and with many continuators, like the "Statistical Society."

We have now definite scope and significance for each and every space upon our diagram. Note (*a*) how mathematics extends to underlie each of the three succeeding sciences; (*b*) how physics extends under its two successors, and (*c*) biology under its one. In short, then, the three great post-mathematical sciences, physical, biological and social, need the above $3 + 2 + 1 = 6$ well-systematised contributions from their respective predecessors, for their own adequate establishment and support. (See Diagram II.)

If the reader will now reproduce our diagram—by folding a sheet of paper twice over each way, and marking on it for himself the four ascending spaces for our four main sciences—these lines of folding will be suggestive. How easy now to fold back, and thus out of sight, the whole column of the social sciences! We have still the whole field of investigation admitted by the Royal Society, the Académie des Sciences, and their kindred contemporaries. Is it asked—Why are the social sciences thence excluded? Nowadays a member of any of them may answer, "Because too inexact" or the like: but this is forgetful of the vagueness from which every science has arisen; and that every such clearing-up is the very life, the intellectual joy, of them. The simple historic explanation is that when these societies were founded, in the seventeenth century, *i.e.* soon after the Thirty Years' War, and still with the Civil War's worst bitternesses around them, nobody could calmly discuss questions of either temporal and spiritual powers without bitterness; whereas there was no Protestant or Catholic mathematics, no Royal or Republican physics or chemistry. The inclusion of Biology, as with Harvey and his fellows, was because these, as medical men, were of especially detached tradition, open to add "Jesuits' mark" to Jewish pharmacy, and fairly utilise their merits.

But Biology—before Darwin, and even amazingly since—is seldom granted such fully important place in the prevailing conceptions of " Science " as that given upon our scheme. Not simply by the ordinary public, but conspicuously in even studious discussions of the social bearings and significance of science, as so much during and after the war, it is physical science that is essentially discussed. And no wonder. Given the potent—even overpowering and all-transformative—predominance of mechanics, physics and chemistry, and of their applications especially, alike for our industrial age and for its wars, it is inevitable that their mechanistic viewpoint and outlook should dominate most minds: formerly with a too naïve optimism of " progress "; and now with converse fears.

For every reason, then, is it not time to be re-stating the place and claims of the sciences of organic and social life; and these in their rational positions and perspectives? And hence towards their clearer applications also; and these not only mitigative, as heretofore in industrialism and in war; but now guiding towards better things, even in time controlling " progress," towards better ways of Life?

Materialisms and Transcendentalisms: " Mechanists " and " Vitalists."—Still, for the moment, just as we lately folded back the social sciences out of sight, so again we may do for the biological—indeed with too few to miss them. Here, however, all physiologists will intervene, claiming rightly, as already noted, their great results and field. Yet when we leave them their square, on the level of physics, for their mechanical, physical and chemical enquiries into living beings, we may still fold off (horizontally) the square of biology, for us its vital essentials; and they, for the most part, are all the better pleased. For what, they say, can you know of anything *vital*, beyond our physico-chemical explanations of it? What is "Vital force," beyond a name at best for forces not yet fully understood? Here then we have clearly come to the great controversy of "Mechanists" (more popularly called "Materialists") versus "Vitalists." This warfare is many ages older than the campaign over Evolution; and ever raising storms like those which evolutionists in Europe now scarcely remember. Why so? Because in yet more immediate and intelligible ways; first obviously medical, then so directly psychological and philosophical, theological too, and moral also: hence far more deeply shaking to all these "foundations of belief." In Huxley's days the controversy seemed to his side practically silenced, with the vitalists in full retreat: yet in ours the latter have greatly rallied: witness, above all, M. Bergson's *élan vital*, renewing Schopenhauer's "will to live." Witness too the revival of Aristotle's "Entelechy," as directive principle essential to the living being, by Driesch; and this not simply as Heidelberg professor of philosophy, but as also a skilled marine zoologist, memorable along with the initiators of experimental embryology. Most combative of all the opponents of the strictly mechanistic school is Dr. J. S. Haldane, one of the leaders of Oxford's productive school of physiological research, and a notable expert on respiration, who has been of the greatest practical help towards miners' safety in peace-time, as with gas-masks in war. While thus technically competent, as are those on the strictly material side, he is yet so convinced of the supremacy of the other, as to say that if he did not personally know, loyally recognise and esteem, the admirable technical competence and fruitful discoveries of its antagonists, he should esteem them as of defective intelligence! Yet our late and lamented friend, Prof. Jacques Loeb—he who first explained how the moth flies straight into the flame, and since then many other "tropisms"—was the very man to return the same acidulated compliment to Dr. Haldane.

Towards understanding this great controversy, the first thing is to face it clearly, and this from both sides; so as to see whether we cannot define the position of its battle-lines upon our outline-map of the fields of science: for we may thus discern, as clearly as may be, what it is that the two sides are fighting for: and this indeed since the days of Democritus, of Lucretius and so on, through the ages, and until our own times. In these we cannot forget the bold invasions of the old world of traditional culture by Huxley, Haeckel and other followers of Darwin's plume; with vivid sallies, of Clifford most brilliantly; nor yet the steadier engineering works Herbert Spencer brought against its philosophers and theologians. More recently we have watched the growing legions who are substantially with Loeb, just dead on the field of honour, against Driesch and Haldane's array, now less numerous, yet again recruiting around the waving marshal-standard of Bergson.

So now to our folding map for the various fields of this long war. The first conquest by the preliminary sciences upon the three vertical columns first assigned to their ascendingly complex successors is that of the application of pure mathematics to illuminate the physical field: but here the resulting co-operative and constructive peace, even mutual aid, is the oldest story of science. And though we have above seen how recent is biometrics, indeed even statistics, any past reluctances of older biology, and even of social studies, are not worth mentioning against the substantial welcome and acceptance, even increasing incorporation, of their contributive mathematical work. Where, then, is the war? Essentially as regards the extension of the Physical sciences into the field and column of Biology.

Its general studies of life are, as we have above seen, essentially initiated from those of man; and these not only from his food-supplies, from his diseases, and so on—whence agriculture, medicine, etc.—but even from his mental life, his moral and social world accordingly. There is here, however, no objection to the use of material things, nor of bringing chemical or physical appliances into the service of life: indeed from common salt to medical ones, from flint tools to iron machines, these have in the main been welcomed. But it was a far more serious and alarming matter, when the physicist, who had thrown aside the old mysticisms and transcendentalisms of his astrology and alchemist grandfathers, entered the fields of life in the same rigorous spirit. This he could not but do; and his results have been great. Our old biological belief in the existence of a permanent distinctiveness of "organised bodies," of "vital processes," and even of "organic matter," from those of the inorganic world, has been, however, successfully broken in upon long ago by Descartes. For he—though a philosopher and a psychologist, was also a great and even transformatory mathematician, no mean mechanician, and a skilled and critical anatomist as well: and thus he gave a reasoned presentment of "Animals as Automata." This doctrine was not a little discomposing, if not shattering, to the naïve old naturalists, with their tales of animal intelligence and even wisdom; and also (despite its cautiously-framed limitations) to the prevailing theological and philosophical, as well as currently scientific views of man, and his simpler life-companions. Again, to abandon old medical traditions, as of "temperaments," "humours," "vital spirits," and the like, could not but be a shock to the old schools of medicine, even those not disinclined to progress.

It is not now necessary to recall in any detail the advances of the chemist, as from progressively building up organic compounds, to elucidating metabolisms; nor of the physiological physicist, as he progresses from simplest muscle-jerk, and then its recorded curve, to subtle readings; nor from reflex action at its simplest, not merely to Spencer's and others' psychology, but to amazing technical unravelments of complex nervous processes and their disorganisations too; and even of brain-action, which to-day culminates in work like Sherrington's, with its main results upon this stricter side.

Return, however, once more to our diagram, and see how in this physiology the physicist runs forward, *under* our main field of Biology, thus keeping clearly upon his own level of its interpretation. For his practical purposes, he is thus folding back this upper field out of his sight, and we must, of course, confess that biologists inclined to the converse before his day. So his aim (and thus, quite logically, his claim) becomes nothing short of appropriating our traditional fields into his own, by re-stating practically all we can see and say, and this anew, with his own vivid clearness upon his material and energic level. So now of this way of thinking every progressive biologist has to learn all he can: indeed our best students, for all the upbringing from nature-study in the open which we have given them, and thence onwards, according to our various lights, are now more and more turning to bio-physics and bio-chemistry, and these increasingly associated: and we cannot but say: So far well! Why drag in "so far"? they may now ask us. They can hardly but suspect we are more or less still with Driesch, and hankering after an "Entelechy," to explain what they are doing so much more plainly in their own way: if not even that we are retreating from biology into philosophy, or at least taking refuge to recruit our own *élan vital* from M. Bergson's unfailing and vivid supplies.

We have to this our answer ready; but let it wait for a later Chapter (IX): since our problem here as yet is but with the general plan of the battlefield, and the understanding of the positions of both sides, and so with not taking either side in it. Indeed, our schema shows both sides, and each in its own way seems justified in holding its positions.

That of the physicists and chemists has just been recognised: yet as for the older biologists, we are with them too, and for each and every one of their eight fields. Our fossils and our classifications, our anatomy are not indeed interfered with; nor is our ecological interest, in the ways of insects or aught else, diminished by the new insistence upon tropisms, instead of on instincts or the like. Indeed, so far as we have here gone, we have not ground for entering on past or present psychology; and as regards that past, we are quite willing to admit that our predecessors were often too bold amateurs. Similarly for the interest of evolutionary studies: those of races and individuals, whatever new light be thrown upon them, will but go on all the better for it. So for the physiology of the self-maintaining life, in all its ranges of organic functioning: while as for that of reproduction—the species-maintaining life—our own previous collaboration in this series (*Sex*) includes not only an outline-introduction to the anatomy and histology, the ecology and physiology of the sexes of animals and plants, but recalls our early interpretation of this, in terms of bio-chemistry and bio-physics; no doubt elementary nowadays, but bio-chemical still. All that separates us naturalists from our extremist friends on that level may roughly first be put, by saying that while we recognise the two sexes of bicycles across the street as well as they, it is only when they have little bicyclettes running of themselves after them that we can quite give up, for their study, our present preference for keeping hens, or breeding puppies, or watching butterfly courtships, dung-beetles' family-provisioning, and so on, or for peering into ferns and flowers.

Such biologic studies, the physico-chemist, however strongly preferring his own research-lines, of course does not oppose: what he promises is better explanations of them. Still, while welcoming all these, and as far as they can go, we maintain that without at all assuming "vitality" or "vital forces" in any of their old metaphysical or occult senses, we are still entitled to claim that the study of organic beings, as Biology, retains its distinctiveness, of self-maintaining and species-maintaining life—in two words "Nutrition and Reproduction"—which distinguishes these as functional wholes, distinct ideas, therefore, from their physico-chemical and analytical presentments, necessarily underlying though these are. We maintain the distinctive autonomy of biology on these simple grounds, despite all interpretations on the plane of physical science. And this substantially as the physicist and chemist clearly distinguish their studies, of matter and energy, from the fields and methods of the mathematician, constantly though they call in his aid, and also gratefully accept and apply all he can teach them.

All this is on our diagram, and so now admits of brief summary. In days long past the terms "Materialism" and "Transcendentalism" were commonly applied to the two sides of this ever-reappearing controversy; and these often as of mutual reproach, yet also sometimes adopted by each, even on banner as well as war-cry. Now it was one of the many and great services of Auguste Comte (for whom, in passing, a renewed interest may be predicted) that in outlining substantially the presentment of the sciences diagrammed above, he also cleared up those two terms in their uses, alternately opprobrious or accepted, by insisting that when we think or speak of materialism, we should recognise it as perfectly "legitimate," within its own limits, though "illegitimate" if going beyond them. Thus the mathematician in his services to astronomy and terrestrial physics is inestimably helpful, increasingly indispensable also: only if he were to go so far as to lose sight of stars or crystals, as in themselves of permanent interest, and think he knows all worth knowing about them from his graphs and calculations alone, would his previous "legitimate materialism" overstep itself, into the illegitimate usurpation of these physical fields. Comte thus defines—we say once and for all—these two types of materialism, the legitimate as the desirable—even necessary, since productive—application of each science to the service and interpretation of the phenomena of the next science upon the ascending scale of complexity (and obscurity) accordingly. Upon our diagram therefore we have already noted our $3 + 2 + 1$ fields for materialisms in this legitimate and productive sense, and indeed as each and all needed, for anything like completeness. Materialisms, then, are legitimate, all are essential: each only oversteps into its illegitimate form if and when it claims to be All-essential: and this whether avowedly or tacitly in practice, by ignoring the distinctive and characteristic ideas of the science we have really been working for.

This, we maintain, settles the matter, and throughout the entire range. Thus Social Science needs—indeed has too long starved for—each and all the three legitimate and productive materialisms which mathematics, physics, and (especially) biology can alone respectively give it. Yet neither (1) statistics nor money-values—nor (2) corn, coal, and oil, with their energy-values for all our machine-age transformations—nor yet (3) population studies, with eugenics added, with heredity and variation, and even "individualism" or "socialism"—since all are still essentially biological readings—can do more than help the social sciences: they can never replace them, whether separately, or all three together. For social filiation, social history, and their outcomes of many kinds, are ideas intrinsically distinct, from each and all of those which distinguish and justify the three main preliminary sciences respectively.

That the like is true for biology in its descending turn is also not hard to see. Thus "heredity" must not only be successively considered and scrutinised in terms of cellular, nuclear, and chromosome units within its own living organic field, but also in terms of continuities of chemical process and composition which will doubtless some day be discovered and analysed by the bio-chemist : and similarly for "reproduction," etc. Yet though the biologist (indeed even the novelist !) may rightly be interested in such discoveries as they appear, each will go on, helpfully enlightened doubtless, yet substantially as before, with his old problems, and in their highest biologic aspect still. Enough then of here materialisms; whether the needed or the extreme.

Transcendentalisms.—But now "Transcendentalisms"? It is asked—Is there any sense in these at all? How can they ever be legitimate, without flying beyond the bounds of positive science altogether? But here the founder of positivism again cleared them up. We may re-state his elucidation, in our own way; so first by recalling that what is now comparative anatomy, with its lucid and penetrating demonstrations of the unity of structure throughout parts so distinct—not only for the plain man, but for the carefully descriptive (but still empiric) anatomist—as bird's wing and man's arm—was actually initiated by Belon's comparison of them. This line of research, however, was long delayed: and when it came, it seemed "Transcendental Anatomy." And though some of its renewers, like Oken, gloried in this term and adopted it, it obviously lacked scientific precision, and so repelled the clear workers, and too much attracted and dissipated vaguely speculative minds, as was too often Oken's own. So when Goethe, for instance, interpreted the flower in terms of its component leaves—thanks not only to his keen insight, but to his observant outsight also, in puzzling over an abnormally leafy rose—his doctrine was long reckoned "transcendental"; and he had thus to coin his fine term "Morphology" (form-logic), to replace his previous "Metamorphosis," thereby also expressing more clearly that such "transcendentalism" is legitimately scientific. But Comte went further, and defined "transcendentalisms" as the very converse—and indeed complements—of his "materialisms." Thus the origination of the biological sciences—each and all the eight of them—from pre-existing fields of social interest, in fact from sub-sciences of sociology, is a clear case of "legitimate transcendentalism" in this sense. So again when the biologist reminds the chemist that the oxygen with which he so commonly begins his teaching of inorganic chemistry is essentially, so far as that of the atmosphere is concerned, the creation of the plant-world, and thus an organic by-product; and that oxygen was actually discovered by Priestley as an enquiring vegetable physiologist; we are here safely within the limits of legitimate transcendentalism, *i.e.* that of a contribution of the complexer science to its preliminary one. And so again with other contributions of biology; say this time to physics and chemistry together. Thus Graham's discovery of osmosis, and his separation of crystalloids from colloids accordingly, was thanks to his use of an organic membrane for his purposes. So too the fruitful physico-chemical researches of De Vries (himself a botanist) and taken up by the chemist Van't Hoff, whence even to Arrhenius and his "ions," were very largely suggested by the plant-physiological studies of Pfeffer.

That physical sciences have in their turn aroused the mathematician to his discoveries of new methods for dealing with them is nowadays familiar; since perhaps never more actively in progress: so the case for "legitimate transcendentalisms" is again clear in principle, throughout our series of the sciences. Here too it will be seen that our diagram provides space on which we may mark out each and all of these legitimate and promising fields of enquiry (again $3 + 2 + 1 = 6$), but as these, to be made fully fertile, have still to be prosecuted clearly and systematically, as are the complemental materialisms in these times, we leave their spaces blank, save for the above instances), and thus as a half-dozen good large conundrums for the reader. (See Diagram II.)

Is it needful to point out the nature of "illegitimate transcendentalisms"? While it is legitimate to use each higher science of our scheme to aid each preliminary one by its own suggestive light, it is illegitimate to allow such suggestion, speculation or questioning to satisfy us; and so to make us forget or shirk the real spade-work of the full preliminary science.

The Subjective Sciences.—So far then our diagram has served: but while it justifies itself increasingly, it is not yet satisfactory, adequately comprehensive. What, for instance, of that omission of Psychology which the reader may well have noticed at the outset, and for which Spencer and subsequent classifiers of the sciences have blamed Comte; so much indeed that in America, where psychology has been so advancing, and where sociology too is generally taught, Comte's importance as initiator of the social science seems commonly reduced to that of a mere precursor. But the answer is, that Comte's "Biology" was of "*Bios*" in its fullest sense, and that it was this full biology that he carried into sociology: indeed just as a "Biography" is no mere organic record of a human animal, nor even of his material work; but, and above all, that of the creative mind which made his career and work together, in overcoming his difficulties of circumstance, even turning them to opportunities.

Was Comte's biology then what Haeckel later called "monistic," but the world more generally "materialistic," and this in the old and still commonest sense? Yes and no: but without entering into this here, let us rather meet the claims of the psychologist for his own field of science, by now adding upon our diagram, below the beetle, the scarabæus, of biology, the butterfly, " psyche," for psychology. That we place this under, has no suggestion of inferiority; we do so merely because we find it convenient, in graphic life-notations, to place the subjective life on the lower half of our space or sheet, and thus keep the upper half (the first looked at) for objective phenomena, and this whether whoever uses the diagram considers mind as a mere " epiphenomenon " of organic life, or the organic life as its manifestation; or again seeks to make what he can of both by turns.

Psychology then has now its space to accompany our biology : so now we have room (though little in this small volume) to note its progress; and here chiefly as regards the comparative and experimental psychology of animals, from Jennings' Protozoa to Pavlov's dogs, not to speak of the psychology of man, now so widely studied.

But in this charting of the sciences, must we not make space for social psychology too, in the next higher field? Surely yes : indeed here in a way, our symbol—the book—already expresses it so far. But not distinctively enough : so to express the claims of social psychology at its highest—*i.e.* as not merely phenomenal, but regulative of human society, and thus above all ethical—permit us now to place below our book of social tradition the ancient symbol of corresponding moral tradition, the stone tables of the Mosaic law.

Have we now adequately provided for the subjective sciences? Not yet: for the humanistic reader may at once remind us naturalistic writers that beside psychology we have still made no provision for the well-known study of esthetics, nor even the ancient and long-established science of logic! So let us look for places for these. Logic has always gone well with mathematics: but it is none the less one of the most characteristic features of science in our own time that the mathematicians are more and more clearly recognising themselves as essentially at one with logic, and as graphic logicians: so this has compelled them—witness Bertrand Russell, as most familiar name among his peers—to revise the whole fundamentals of their science accordingly. Hence now, below our tri-axial symbol of mathematics, we place the corresponding swirl of logic. (See Diagram II.)

Esthetics still remains—where place it? When all is said for the beauties of human arts, and of living nature too, the fullest impression of beauty, since here most fully sublime, is cosmic above all, from snows to sea, from stars and planets to moon and sun, and thus, from simplest warmth and light, through all the ecstasies of vision. Indeed as the wonders of the sky have aroused the astronomers, and those of landscape the geologist, may we not even thus interpret esthetic impulse to the physicist also? From Pythagoras discriminating the octave, to Helmholtz with his resonators, to Kelvin and others with their new instruments, to Einstein with his violin, are these not musicians? And the physicists of light—how better and more naturally could they have come to the first interpretation of the rainbow, or to the making of it anew with the prism, as from Newton to the spectroscopists, than by way of their natural, and thus even childlike delight in its impressive beauty and colour? Is it not also the sheer beauty of the butterfly, the shell, the flower and leaf, that oftenest first awakes the naturalist? And so is it with the great works of man for the historian. Yet since the appreciation of cosmic beauty stands primitive and paramount, let us place one of the many possible esthetic symbols (the rainbow) above the field of physical science.

Does this full scheme of knowledge, now with objective and subjective sciences adjusted together, thus seem to have extended too far? —not only beyond the customary limits of biology, but of its actual needs for progress and security? If so, it is for the critic to say which of them all he is prepared to leave out. Certainly not the physical world, else what would we know of the material environment of life, and of the conditions this imposes—or even of life's internal physiology. No mathematics?—then no adequate physics, and certainly no biometrics. No logic?—and yet biology is all but the most intricate of all the "-logies," and thus at once greatly initiated by, and educative of, the master of logic himself, the physician and biologist Aristotle. No psychology?—Impossible! (Chap. VIII). No ethics?—Then no full understanding of either the species-regarding or even the self-regarding life, let alone of social life. And no sociology? What then of our eugenics, and all other would-be applications of our science, from medicine and public health to agriculture and forestry. In fact what would become of the whole needed reshaping of our human environment, the raising of our deteriorated modern human hives—nowadays for the most part but "slum, semi-slum and super-slum"—into Cities indeed? That is, designed as all that human life in evolution should have them, and towards its best, and thus not only freed from the evils which now so plainly threaten our whole civilisation, but this by raising it to new heights, those of the City in Deed. But this can be no mere "*Municipium*," but "*Civitas*" complete; and with more than "*Pomarium*" around. Its "*Pagus*" also, its whole "Diocese"—the new Attica of each new yet truly modern Athens; and all, too, as no mere Utopia, but as concretely realisable Eutopia—City and Region again one. The "Promised Land" of old, and even its "Holy City"—in short, the coming Kingdom of the Ideal—this, and nothing short of it, awaits the highest collaboration of biologist with sociologist, in practice together, and with help of all their preliminary guides and teachers too. From our deteriorated, and deteriorative, human hive to the city of Parnassolympians in Eutopia may be a long labour; but it is none the less the task which these two applied sciences, with help of all others, are now clearly planning: for what other use fuller and higher than this, of fulness and all-comprehensiveness of City Design? And for the critic mind, however discouraged, even to cynicism, as for the practical mind, however materialised, even to mammonism and mechanicalism multiplied together—as are well-nigh all minds so much to-day—is there not encouragement in the fact that what these alike at heart find best, and value most, in the cities and regions through which their life-path runs, are the surviving or renewing endeavours to realise the ideals of their respective times—religions in their temples and cathedrals, learning and science in their schools and universities, arts in monuments in all these, yet also for homes?

Each and all of the sciences has now been seen to bring vital aid to biology: and hence the need and service of their orderly grouping, and thus towards future utilisation more full than heretofore.

CHAPTER VII

THE TRAJECTORY OF LIFE

A STEEP-CURVED bridge has been often, and both to writers and artists, a symbol of the general curve of human life, and not simply for the chances of death, as in the *Vision of Mirza*, or in Walter Crane's vivid illustration for Karl Pearson. Infant and child, youth and adolescent are on the ascending curve, to where maturity culminates. Then soon begin the first hints of ageing; and life's descent continues through senescence, to death. Similarly in the animal world, but with great variety of detail, as sequent phases, the ascending especially, may notably lengthen or shorten. In the plant world there is the familiar, but always vivid sequence—germinating, shooting, leafing, flowering, fruiting, seeding and withering.

Many animals are annuals, like the little translucent fish, *Aphia pellucida*, and perhaps as high up the scale as the common shrews. Among plants the annual rhythm is more familiar, the life-curve being so plainly correlated with the march of the seasons—the ascent corresponding to spring and summer, when the energy-gaining conditions for nutrition are most propitious, while the descent marks the weakening of reactions to the sterner environment of autumn and winter. But as organisms gained firmer foothold and in efficiency of internal working, there was extension of life, variously increasing. The main trajectory must now be thought of as showing ups and downs, In short, life's intrinsic rhythm is punctuated by seasonal periodicities. Habit blinds us to the wonder of the contrast between the exuberantly growing vine and its leafless winter sleep. For a strikingly curious case of this periodicity, take the Palolo worm of Samoa (*Leodice viridis*), which has its nutritive and reproductive see-saw, but the time of starting a new generation in prodigal abundance seems to be determined by the moon. It occurs with remarkable punctuality at the last quarter of the moon in October and November.

Duration of life differs widely in different types; but, save for tree-rings, it has taken long to get exact data, and these in too few cases. For careful discussion we refer to Sir Ray Lankester's *Comparative Longevity* (1870), and to Weismann's famous essay on *The Duration of Life* (1881). Giant tortoises have been credited with 250 years, elephants with 200, eagles with 50, toads with 40, crayfish with 20, blackbirds with 18, and so on; but it is plain that the natural span cannot be safely inferred from that exhibited in captivity. One welcomes, therefore, new methods, like that of "scale-reading" in fishes, by which it is possible to tell the age to a year, just as in the case of trees. But while the reading of this scale-calendar is easy in the case of the salmon, it is very difficult in that of the herring; and experts differ with ichthyological fervour.

What determines such varying spans of life? There are two kinds of answer; supplementary, not antithetic. The first lays emphasis on physiological factors. On the one hand, there are long-lived constitutions, marked by abundant anabolic storage, a smoothly-working endocrine system, resting habits, and not too costly reproduction. On the other hand, there are short-lived constitutions, relatively more katabolic, with little or no storage, often living dangerously, and with modes of reproduction that severely tax resources. The other kind of answer—strongly represented by Weismann—regards the length of life as determined by Natural Selection; since in given conditions those types would survive that have their duration of life adjusted to their chances of death and to their rate of effective multiplication. Forms that lived too long and continued to multiply when on the downgrade would automatically come to an end.

Every life-insurance office knows of different normal lengths of life in mankind, as notably for the two sexes, and for different races also; but the phases of life also vary according to constitution and temperament. There are individuals with prolonged youth (and towards this does there not seem to be a present-day trend?); there are others with prolonged maturity; others again, like vigorous octogenarians, with prolonged senescence.

It is interesting to apply this idea to lower organisms. There is sometimes, for instance, very slow embryonic development; thus the period of ante-natal life for an elephant is thirteen months. Strange to say, as long a period is required before the viviparous birth of Peripatus, an archaic annectent type between Annelid worms and Insects, themselves usually of rapid development. On the other hand, embryonic development may be extraordinarily rapid and compressed, as to three weeks for a rat, or to a day for a midge.

Sometimes, again, there is an interpolation of a larval period, during which a young form, quite unlike its parent—a caterpillar, or a tadpole, for instance—accumulates stores of food-material, gets away from the too exacting conditions of its birthplace, or secures some other advantage. The antithesis to this is seen when the egg hatches into a miniature of the adult, as in types so widely diverse as spider, earwig, and skate.

The larval period is sometimes very long—two and a half to three years for the European eel, four years for a cockchafer and no less than seventeen years for one of the cicadas. But while larval lampreys continue for four years, the tadpole's metamorphosis is accomplished in three months, and that of the bluebottle in as few days.

Sometimes there is a long-drawn-out succession of stages. The shore-crab's egg gives rise to a "zoæa" which swims out into the open waters; it feeds, grows, and moults several times; it changes into another form ("megalops"); this sinks to the bottom, metamorphosing into a miniature crab, which creeps up the slope to regain its birthplace on the shore. So in the more familiar case of the salmon, the sequence is—egg, alevin, fry, parr, and smolt; the last making strenuously for the sea when it is about two and a quarter years old. What a contrast is all this with direct development, as when a young plover, more fully finished than a chick, breaks its way through the egg-shell.

In many mammals there is a prolonged youth, and this often a playing period, of great importance as a time for testing not only innate instinctive aptitudes, but any new variations as well. How different from the very short youth of some of the Australian mound-birds, immediately hurrying into the scrub from the nest, which may be near a hot spring or in the midst of a heap of fermenting vegetation. In some cases they are actually able to fly on the day of hatching.

Adolescence is sometimes gradual, with its slow dawning of sex, as in many birds and mammals; but it may also come on like a sudden storm, some insects pairing immediately after their emergence from the chrysalis. There is often a long life of maximum strength and maturity, as in salmon and tortoise, eagle and elephant. Or the curve may drop almost perpendicularly from its height. Thus lampreys and eels die after spawning; many butterflies never recover from their egg-laying; and there is an extraordinary abbreviation in one of the Ephemerids or Day-flies, whose whole adult life is one brief hour! These instances must suffice to illustrate the idea that the life-histories of different animals differ in the *tempo* of different parts of the general curve. For the plant world the same holds true: thus the flower of the common garden day-lily (*Hemerocallis*) literally deserves that old name, while a flower of slipper-orchid (*Cypripedium*) may last three months.

But what factors are there to alter the course of the life-curve? and even the "tempo" of its different phases? This opens large fields for investigation: only the arrangement of the possible factors can be indicated here. They may be environmental, functional, or organismal.

(a) *Environmental.*—In cold waters the rate of protein-metabolism is slowed; fewer cell-divisions occur, the duration of life tends to be longer; and there are thus more generations living at the same time. Hence the medley crowds of plankton are denser in northern seas than at the equator. Life is slow in the great abysses; in tropic waters it is often hurried. Stimulating food hastens development; uncongenial diet hinders, causing Planarian worms to be "born old." Ultra-violet rays may act as a growth-tonic; and other influences may be traced to changes in weather and climate.

(b) *Functional.*—The reproductive function may come to be a violent crisis; thus, as we have noted, the Palolo worm has to sacrifice all its body except the anterior end. When alimentation is greatly reduced in adult life—even to vanishing-point in some insects—the period of maturity is bound to be short. Man is a plastic organism, and his life-curve can be modified by changes in occupations and in functionings generally. So many animal life-histories admit of parallel interpretation. Thus a roving creature like the otter, with its several homes and frequent journeys between, remains singularly young, and even playful, throughout its adult life. May not the youthfulness and joyousness of birds be connected in part with the prevalence of migration (so much wider than we used to know), which implies two summers in the year and stimulating changes of habitat and habits?

(c) *Organismal.*—In a few cases, duration of life has been proved to be a definitely heritable character, though probably dependent on several linked factors. And just as germinal variations probably find expression as changes in the total duration of life (in the much-investigated Drosophila, for instance), so they may lead to a lengthening out (or a shortening down) of different arcs in the life-curve. Variations in the hormone-producing activities of the endocrine glands may account for some of the differences between allied organisms, as

Keith has suggested for human races; and these might well alter the length and intensity of the phases of the life-cycle—though these variations have to be accounted for. As the hormone-output of the supra-renal gland is intimately correlated with emotional disturbances, such as anger and fear, it is not so far-fetched as it may seem to ask whether psychological, as well as physiological, factors do not operate in altering the life-curve. As was wisely said of old time, "A merry heart is a continual feast," and "A merry heart is the life of the flesh."

In the main we have been suggesting a threefold physiological reading of life-histories; and this, though only incipient, is primary. Yet it requires to be supplemented by an attempt to interpret the diverse forms of life-curve as each and all *adaptive* to particular circumstances. What is the ecological significance—and, more generally, the survival value—of these strange differences of time and tune?

Our answer cannot be more than illustrative. Many shore-animals have open-sea larvæ, and the pelagic period may be prolonged. This saves the delicate early stages from the great risks incident on the rough-and-tumble life of the shore. It also introduces the young forms to the abundance of the plankton feast. Moreover it helps in diffusion, and towards cross-fertilisation too. Thus free-swimming and sexed medusoids, set free from fixed asexual hydroid colonies, secure cross-fertilisation—a matter of the widest evolutionary advantage.

Yet the reverse curve-change is frequent among fresh-water animals, whose larval stages tend to be suppressed. This is at once intelligible, however, when we think of the risks of being swept downstream to the sea, or of being left in stagnant water after a flood. Thus the newly-hatched fresh-water crayfish is almost a miniature of the adult—a directness of life-history strikingly contrasted with its circuitousness in the shore-crab. Not only is there a telescoping of the larval life in the crayfish, but the young creature is sheltered from risks for a short time under its mother's tail. In the shore-crab the larvæ swim away immediately after hatching. It may be objected that an abundance of insect-larvæ, *e.g.* of Dragon-flies and Stone-flies, is conspicuous in many a river; but the explanation appears when we look at their varied adaptations for taking a firm grip of plants or stones. The caddis-worm, with its heavy case, is also weighted like a diver. Similarly, the brook leeches are nothing if not suctorial, clinging readily to sticks and stones, and some of the young forms hang on for a long time to their parents.

When the conditions of life demand it, there is a prolongation of the ante-natal period; and what steps out into the world is a more or less fully-formed young creature. Thus the foal is better equipped at birth than the calf, and this is adaptive to their differences in habit.

For in natural conditions the cow hides her calf in the thicket, whereas the foal has to stumble along after its nomadic mother. Correlated with this is the fact that the calf enjoys a prolonged meal, sucking to repletion, while the foal is suckled hastily, but at frequent intervals. Hence too the cow's udder is so large, and the mare's so small.

But the prolongation of the ante-natal period (gestation in mammals) may be advantageous in another way, as Robert Chambers pointed out long ago. It may admit of the development of a larger brain before the time of critical testing begins. Thus the various centres of the brain-cortex will have reached a higher grade of organisation before they begin to be flooded with sensory news from the outer world, or taxed by the requirements for control—whether of eye-adjustment, manipulative dexterity, or of agile movements in general. These instances of interpretation in terms of fitness must suffice; the student will readily cap them and develop them.

Every part of life's trajectory has had its monographer, yet the work of interpretation is still young. What an interesting series the monographs make—such as Brachet on the egg-cell, Balfour on embryos, Miall on insect larvæ, Groos on the play-period, Stanley Hall on adolescence, Hilzheimer on sex, Child on senescence, Pearl on death!

But what we need first of all is not the monographer's detailed description of this or that phase of life, but rather a synoptic view of the whole trajectory—the microcosm of the germ-cells, the developing embryo, the period of youth and play, the crisis of adolescence, the time of sex and reproduction, the strength of maturity, the almost imperceptible beginnings of ageing, the definite senescence and the various forms of death. Similarly for the higher plants, we must see the sweep of the curve from egg-cell and pollen-grain, embryo and seed, to germination and growing seedlings; and from the full vigour of the vegetative period with its leafing and branching, to the reproductive period with its flowering and fruiting, after which come the withering and fading to the rest of winter, or to a death which cannot be evaded.

CHAPTER VIII

BEHAVIOUR

In the first half of the eighteenth century the work of the versatile Réaumur greatly deepened the open-air study of insect-behaviour. He had a high standard of accuracy, inexhaustible patience, and an unusual rigour in keeping anthropomorphic interpretation from mingling with his records of observed facts.

A century later the mantle of Réaumur fell on Fabre, "that inimitable observer," as Darwin called him.

Fabre.—He had what Meredith calls "a love exceeding a simple love of things that glide in rushes and rubble of woody wreck." He discloses to us their everyday tasks, their arts and crafts, their shifts for a living, their triumphs and defeats in the struggle for existence, their courtships and marriages, their domestic and even social economy. What were Fabre's great gifts? First, unusual observing powers. After every chapter of the "*Souvenirs Entomologiques*," we say, "What eyes!" "I *scrutinise* life," he explains; "precise facts alone are worthy of science." "See first of all, and argue afterwards." In his sense of the dignity of facts, in his high standard of precision, in his appreciation of the seemingly trivial, he comes, indeed in spite of himself, into fellowship with Darwin, whom he never appreciated. Second, to his observing power he added sympathy; and the result was *vision.* In his insight he got nearer to insects than any one before or since; it was "instinct pursuing instinct."

Fabre was a man of strong convictions, with little capacity for compromise. So sure was he that organism transcends mechanism, that he was contemptuous not only of all mechanistic explanations, but even of the researches of the bio-chemist and bio-physicist as well. He was so convinced that instinct is a big underivable fact, quite different from intelligence, that he did not realise how often the two kinds of behaviour—reflex and reflective—are intermingled. So familiar was he with the subtlety and mysteriousness of life that he was impatient with what seemed to him a too-facile evolutionism. But in the history of biology he remains the greatest discoverer of the intricacy of animal behaviour.

Experimental Study.—Splendid as were Fabre's achievements, however, they were blurred by this hostile attitude to evolutionary thinking, by his view of "instinct" as a mysterious entity, and by his tendency to fallacious though fascinating anthropomorphism. These were defects of his qualities, which the modern movement seeks to correct. The study of animal behaviour has become more precise and experimental; its interpretations are more critical. This welcome change began in the pioneer work of Lubbock (Lord Avebury)—with his experiments as well as observations on ants, bees, and wasps. It was continued on more psychological lines by Romanes, who applied the evolution-idea with enthusiasm and erudition. A great impetus has come from Lloyd Morgan's still more careful experiments and analyses, which quickened the development of comparative psychology, and saved it from exuberance by insisting on the principle that no act shall be ascribed to a higher mental faculty if it can be adequately interpreted in terms of a simpler one. From another starting-point a big advance is due to Loeb, who pressed to its very limit—indeed sometimes beyond it, we think—the physiological mode of interpretation, as contrasted with the psychological. The science of behaviour is still very young, but the old anecdotalism has been left behind and methodical precision has emerged.

Inclined Plane of Behaviour.—Towards broadly reviewing the long line of ascent, physiological and psychological together, let us try to arrange the various kinds of behaviour as steps upon a gradual incline. We observe a minute infusorian exploring in our microscopic field; it works its way vigorously among the alga threads, almost like a dog through brushwood. It is reacting to the diverse stimuli of its environment, and at the same time obeying the fundamental urge of hunger. If it were the size of a shark, and we were in its vicinity, we should not have any doubts as to its purposiveness! Its movements are very different from those of a loosened gun, as it rolls about on board ship.

But definite modes of reaction may become racially engrained; and we see a simple expression of this in the behaviour of a slipper-animalcule (Paramecium). It has one answer to almost every kind of menacing difficulty, whether a sharp-edged obstacle, a diffusing chemical, a zone of heat, or anything else. It reverses the action of its cilia, and thus backs away from the difficulty; it moves slightly on its own axis, feels round with its anterior end, and then advances again on a new line. If it does not clear the obstacle it repeats the performance, and goes on doing so till it succeeds or is killed. Another infusorian, the trumpet-shaped Stentor, has improved on the simplicity of Paramecium; for it has a number of different reactions, and in difficult circumstances it tries one after another, and may in this way solve its difficulty. This is the beginning of the "trial and error" method, which grows commoner as we search the ascending scale of animal life.

Sponges, though often with large bodies, have no differentiated nerve-cells at all; yet there are some that narrow their exhalant openings in the face of an intruding worm. That is to say, the muscle-cells forming the sphincter-ring around the opening are themselves sensitive to stimulus; they are "receptors" as well as "effectors." But when we pass from sponges to sea-anemones, we find definite nerve-cells, and with distinct linkage between these and certain muscles. Here, in its beginnings, is an apparatus of reflex action: for we see the tentacles immediately contracting on the prey that has fallen into their midst. There is here a structural linkage that works well, in nine cases out of ten—a time-saving, energy-saving, and often life-saving racial advance.

At a slightly higher level, as in some of the simpler movements of earthworms, a further step is to be noted. Between the sensory "receptor" and the muscular "effector" there is now interpolated a "motor" nerve-cell. And when we see an earthworm discriminating the light footstep of the dangerous blackbird from unimportant stimuli by jerking itself back into its burrow, we are observing a reflex action with a fourth link in the chain. For the thrill of the sensory nerve-cells passes through their fibres to associative or "adjustor" nerve-cells in the ganglionated cord, whence the stimulus is shunted to the motor nerve-cells, which command the effector muscle-cells to contract. It is well for the earthworm that it does not take all this time to get into its burrow!

Beyond such simple reflexes, there are various compound ones, as where a hermit-crab adjusts its body and many limbs into its sheltering shell, for here the main body sequence of four links has to correlate with all the minor ones, which may be activated simultaneously or in succession. Again, when a young nestling opens its mouth at the touch of food in its mother's bill, and then proceeds to swallow, the behaviour is still reflex, but now much more complicated than that of the anemone when it closes its tentacles on food.

The next level is that of "tropisms," by Loeb called "forced movements." By a tropism is meant an inborn and automatic working adjustment of the body, so that the two sides—or it may be the two eyes, ears, or nostrils—are equally stimulated. In short, it is an automatic means of securing physiological equilibrium. When a moth is flying quickly past a candle it has its right eye much more illumined than its left; so there is bound to be asymmetry or inequilibrium in its neural and muscular activity. This tends to right itself automatically, so that equal stimulation of the two sides is once more attained. The moth's body is swayed round, so that the two eyes become equally illumined; thus the insect obtains a straight course, which accounts for its flying with the flame. Yet the same tropism, here destructive, since a flame is no part of any insect's normal environment, might have turned it straight to its flower. It may further be noted that if the moth were to turn outwards, away from the candle, when first it came within its sphere of influence, then both eyes would be equally *non*-illumined, and safety would be secured. There are some animals that behave in this way, called by Loeb "negatively heliotropic"; but most moths, even when nocturnal in habit, are "positively heliotropic."

Another interesting feature in the behaviour of some animals is the reversal of the tropism when a certain limit is passed, or when there is a notable change either in their environment, or, as we shall see, in their own constitution. Some animals, like scorpions and crayfish, which are constitutionally light-shunning, avoiding mild illumination, are unable to keep away from a bright light, such as that of a fire or a torch: so that scorpions creep up to the camp-fire and crayfish come to the lure. The little "fresh-water shrimps" or Gammarids, so common in brooks, are light-avoiders, but the addition of a few drops of acid to their water in an aquarium is found to change the sign, as it were, and render them positively heliotropic. Some caterpillars are constitutionally wound-up to climb higher and higher, and thus they reach the tender upper leaves on a plant; yet when their physiological condition begins to change, at their limit of growth, their tropism reverses, and they become as bent on going down as formerly on going up. This is plainly advantageous, since they are about to become chrysalids underground.

Important as these tropisms are, careful experiment must be made to avoid the temptation of simply *labelling* a kind of behaviour as a helio-, thermo-, chemo-, geo-, hydro-, thigmo-, or other tropism. How many tropisms would a visitor from Mars detect in mankind, and how falsely simple his biology would be! It should also be carefully noted that just as a reflex action can be sometimes inhibited (*e.g.* a sneeze at a wedding!) so tropistic movements may be interrupted by individual initiative or modified by some stronger impulse.

There is no doubt, however, that these obligatory movements play an important part in the behaviour of animals. Let us take an instance from the habits of mosquitoes. The deeper note in their buzzing is the same in the two sexes, and due to their wing-strokes; but there is a shriller note, apparently confined to the females, which is produced by the vibrations of tense membranes at the openings of some of the anterior breathing-tubes. When the male hears this sound he is conspicuously excited. If the note be produced artificially in the vicinity of a tethered male, he exhibits a sympathetic quivering of his bushy antennæ and he adjusts his body so that both are equally stimulated. Though direct observation is difficult, a similar orientation doubtless occurs in freedom, and the flying male is thus almost bound to find the urgent female. In some cases, the females spontaneously seek out the swarms of buzzing males, but this fact does not affect the probable utility of the tropistic movements of the other sex.

Somewhat different from any ordinary tropisms is the behaviour of the newly-hatched

Loggerhead Turtle, which hurries from its cradle in the sand of the shore, and makes for the sea even against obstacles. The experiments of Howard and of Parker have shown that the young reptile is not guided by smell or hearing. It is constitutionally bound to go down a slope rather than up (positive geotropism); it seems to be more influenced by blue than by other colours; and these two idiosyncrasies may well help it seawards. But the most important reaction is found to be that of moving away from the more blocked and interrupted horizon and towards that which is open and free. Inside a tub, out of which it cannot see, the inexperienced young turtle moves anyhow, as long as the tub is kept flat. But on the top of an inverted tub, where it has a good view, it first moves round in a little tentative circle, and then moves towards the more open horizon, which is usually in the direction of the sea. If there is a copse between the turtle and the sea, and an open field on the landward side, the animal will go the wrong way. Its impulse urges it towards the more open horizon. Parker's careful study of the young Loggerhead's persistent seaward movements is a fine example of the precise experimental study of behaviour that marks the modern temper.

Slightly different from tropisms are intrinsic rhythms that have taken firm hold of the constitution. Thus the well-known Planarian worm, Convoluta, abundant on the flat beach at Roscoff, ascends to the surface of the sand whenever the tide goes down, and disappears below the surface at the first splash of the returning wave. This is more than reaction to stimulus; for if the worms are transferred to a tideless aquarium, or even to a glass tube, with sand and sea-water, they continue for some days appearing and disappearing at intervals corresponding to the rise and fall of the tides. In this case the organic rhythm goes on independently of the normal external stimulus. The same tidal enregistration has been observed in the behaviour of some other shore animals, such as hermit-crabs and sea-anemones; and diurnal periodicity has been observed in the movements of leaves of Acacias kept in the dark. Indeed, have we not here a clue towards better understanding of the annual rhythms of the higher plants? And perhaps also of the ways of migrating birds?

These reflexes, tropisms, and rhythms illustrate a kind of behaviour that is the expression of linkages hereditarily established between particular nerve- and muscle-cells. Yet there are many cases where such explanations seem too simple, as when an animal shows individual initiative and adjustment, though still hardly to be credited with intelligence. Thus among the common starfishes on the shore (*Asterias rubens*) Prouho has observed that some individuals more than others are given to attacking small sea-urchins, which are not only as prickly as hedgehogs, but are equipped with hundreds of minute snapping-blades (pedicellariæ), some of them poisonous. The starfish lays one of its arms on the sea-urchin, which responds by reflexly clinching scores of its snapping spines on the soft suctorial tube-feet of the aggressor. Whereupon the starfish draws away its arm, wrenching off the pedicellariæ, which are unable to let go. It then repeats this performance with another arm, and then with another. When the sea-urchin is thus more or less disarmed, the starfish begins to protrude on it its very elastic stomach, which has poisonous as well as solvent juices, and thus soon makes an end of the urchin. This is an instructive case, for it is only some individuals among the starfishes that tackle sea-urchins; moreover, what is attempted has to be persisted in until it is finished, if it is to be of any use. No one can speak of the starfish as here following the line of least resistance. It is exhibiting experimental behaviour; yet we dare not speak of intelligence when dealing with an animal whose nervous system shows no concentration into ganglia.

The next great stretch on the inclined plane of animal behaviour is that of Instincts. This term is best used in the plural, or as an adjective; for it includes a variety of activities, by no means all on the same level. Instinctive behaviour again requires inborn pre-arrangements of particular nerve-cells and particular muscle-cells, but these to a much higher degree of complexity than for tropisms. In its psychological aspect, though instinct may be suffused with awareness, and even backed by endeavour, it does not require to be learned. It reaches its fullest, clearest and finest expression in the "little-brained" ants, bees, and wasps; just as intelligent behaviour—in which there is some degree of perceptual inference, some "picture-logic" at least—is at its best in the big-brained mammals. It is highly characteristic of birds, again, that intelligence and instinct are subtly mingled in their fascinating behaviour.

Where can we find better examples of instinct than in Fabre's *Souvenirs*? He tells us of the Calicurgus wasp that stings its captured spider near the mouth, thereby paralysing the poison-fangs; and then, safe from being bitten, drives in its own poisoned weapon with perfect precision at the thinnest part of the spider's cuticle, between the fourth pair of legs. Again, he gives a quaint picture of the queen-bee of the Halictus family, who, past all maternity, becomes in her worn old age the portress of the establishment, shutting the door with her bald head when intrusive strangers arrive, yet opening it, by drawing aside, to any member of the household.

Take another picture; for these subtleties of instinctive behaviour must be included in our total impression of the characteristics of life. Fabre tells the story of the solitary digger-wasp, Ammophila, which drags stupefied caterpillars to the living larder which she stocks for her offspring. The victims must be paralysed, lest they should crawl away. Yet they must not be killed, lest they should rot, or perhaps dry up. So the digger-wasp quickly stings its caterpillar in the three nerve-centres of the thorax; it does the same less hurriedly for the abdomen; it then "maks siccar" by crushing in the sides of the victim's head. The result is a paralysed and concussioned caterpillar, which cannot possibly recover. Now this ghastly manipulation requires no apprenticeship; it is perfect the very first time; it expresses an irresistible inborn impulsion (Fabre said "inspiration"), engendered who shall say how? It may—indeed so far does—look like intelligence; but when we disturb the wasp in its routine, it falls into mere confusion; the difference is at once apparent.

To instinct, everything within the routine is easy; but the least step outside is difficult. The mason-bee makes a mortar nest with a lid, through which, when fully grown, and ready to begin its metamorphosis, the grub cuts its exit. If we put on a piece of parchment in actual contact with the natural lid, the additional thickness makes no difference to the grub, which soon cuts through the extra layer. But if a pill-box, even of paper, be adjusted a little way above the natural lid, so as to form an empty chamber, the grub, emerging into this closed space between the lid it *has* cut through, and the extra obstacle it *could* easily cut through, can do no more, and dies. As far as its bodily powers are concerned, it is free to act as it formerly did, so it should easily gnaw its way out; but this is inhibited by the stereotyped character and build of its psycho-physical organisation, which we call instinct, and that works so well as long as routine is not disturbed. When the wasp-grub emerges from its cradle, it has done all its cutting; it cannot begin again. So it dies in its paper prison, for lack of the least glimmer of intelligence. Thus we see a forking of the ways of life; between *instinctive* behaviour—with its ready-made capacity for doing apparently clever things—and *intelligent* behaviour—always with some appreciation of the relations of things, and the significance of the situation. If a bell-jar be placed over the nest that some species of wasp make underground among the moss and grass, the incoming wasps soon manage to effect their entrance under the edge of the glass. Yet neither they, nor others of their kin, can come out again. How so? Because while they must alight to enter, and then creep, they are instinctively accustomed to *fly* out!

Similarly, when Fabre captured a long Indian file of Procession Caterpillars, adjusted its length to the circumference of the stone curb of a fountain in his garden, and then brought the head of the first into contact with the tail of the last, they continued for a week crawling round and round in futile circumambulation—a striking instance of the limitations of instinct. As Fabre said, "Ils ne savent rien de rien." A gleam of intelligence would have broken the spell: yet it must be noted that an animal which is in some respects intelligent may show nothing of this in stretches of behaviour which have become thoroughly instinctive. Thus it is an error of interpretation to call a pigeon "unutterably stupid" because it may continue brooding on nothing, while its stolen eggs lie exposed only two or three inches away. The brooding activities in such varieties of domesticated pigeon have been entirely "handed over" to instinct, and there is then no interference on the part of intelligence.

By intelligent behaviour—as in apes and monkeys, dogs and horses, rooks and parrots—we mean chains of actions that we cannot make sense of without crediting the creature with some capacity for putting two and two together, in fact, forming a simple judgment. Intelligent behaviour is distinguished from instinctive behaviour in requiring to be *learned*; and it implies some understanding of the situation. The animal is *not* hopelessly nonplussed when details and particulars are altered. Romanes distinguished intelligent from rational behaviour by regarding the psychological correlate of the former as *perceptual* inference, and that of the latter as *conceptual* inference. There is no known case of animal behaviour that makes it necessary to suppose that general ideas enter into their simple judgments. Reason remains man's prerogative—occasionally exercised.

When the rook lets the fresh-water mussel drop from his bill so that its shell is split open on the gravel, we may begin to think of intelligence. So when the Greek eagle lets the tortoise in its talons fall on the rocks far beneath, so that the carapace impregnable to his beak is broken. Beavers sometimes cut a canal right through an island in a big river—a labour not rewarded until it is finished. A higher level of intelligence is well illustrated by the sheep-dog's assistance to the shepherd in a difficult situation, or by the elephant's work with the forester.

In his *Minds and Manners of Wild Animals* (1922), a treasury of interesting observations, Dr. Hornaday, director of the New York Zoological Park, gives many instances of his orang's extension of its discovery of the lever, one of which may be quoted. "For a long period, Dohong had been more or less annoyed by the fact that he could not get his head out between the front bars of his cage and look around the partition into the home of his next-door neighbour. Very soon after he discovered the use of the lever, he swung his trapeze bar out to the upper corner of his cage, thrust the end of it out between the first bar and the steel column of the partition, and very deftly bent two of the iron bars outward far enough so that he could easily thrust his head outside and have his coveted look."

At this stage we may profitably turn to the *individual* registration of the results of experience. When a starfish is turned upside down over and over again, it "learns" to right itself with increasing rapidity. At the end of a week it does quickly and without wasted exertions what required to begin with a long time and various futile tentatives. As the starfish has no nerve-centres or ganglia—no brains, in short—we are not warranted in going beyond vague surmise as to any *mental* aspect of its behaviour. There is a chain of movements; and, in virtue of frequent repetition, one link follows another with increasing facility. Bodily habituation is thus acquired.

When a sea-anemone is offered a fragment of flesh, the tentacles grasp the gift and pass it to the mouth. They will do this over and over again; and if they are then given little pieces of blotting-paper just touched with beef-juice they take these also. But they soon begin to distinguish between the faked food and the real, and will throw off the blotting-paper into the water. After a short pause, the offer of another piece of paper is rejected at once; after a long pause it is accepted as at first. One is tempted to call this the beginning of remembering and forgetting, and so it may be; but it must be understood that the sea-anemone has no nerve-centres or ganglia, but only nerve-cells. Perhaps memory is too generous a word for the sea-anemone; yet here is proof of a registration of experience, so that subsequent behaviour is definitely affected. The limitations of an animal that has no central nervous system may be illustrated by an experiment made by Prof. G. H. Parker, who educated the tentacles on one side of a sea-anemone so that they refused faked food, which those on the opposite side at once accepted. The experience of the educated tentacles was registered in them, but it did not reach or influence those on the other side.

The Venus Fly-trap, an insectivorous plant of the Carolina swamps, will respond twice or thrice to the stimulus of something that is a little like the touch of a fly, but has nothing of a fleshy nature about it. After a few deceptions, however, the trap refuses to work! Here, then, without differentiated nerve-cells at all, there is a useful registration; it keeps the plant from answering back to the irrelevant. More technically, the enregistered result of the experience is effective in inhibiting an unprofitable reaction. This formula is so general that one sees at once that it applies at much higher levels—for instance in Man's games of skill, where excellence depends in part on the elimination of unprofitable movements. The fly-trap's "memory," like the sea-anemone's, is very short; after a brief interval it allows itself to be cheated again.

What a long gamut from the short "memory" of sea-anemone and Venus' Fly-trap to the long memory of elephant and horse! But is not the gist of the matter the same throughout —the engraining or enregistering of an experience, and then the reviving of it, so that subsequent behaviour is appreciably and relevantly affected? There is (*a*) the retention of an impression; there is (*b*) its recall or revival, and finally (*c*) the quickening or slowing, prompting or inhibiting influence that the organic reminiscence exerts on subsequent behaviour. In the lower reaches of the animal kingdom the experiences that find registration have mainly to do with hunger and sex, with self-preservation and kinship. An important part of the early education of all animals consists in establishing associations between signals and actions. Let us take an example slightly more intricate.

When the lips of a water-snail are touched with a fragment of suitable food, the mouth makes three or four tentative munching movements. If the head of the mollusc is touched with a glass rod whenever its lips are touched with food an association is gradually established between the touch of the glass rod and the touch or taste of food. So firm becomes the grip of this new association that by and by the touch of the glass rod suffices to evoke the munching movements although no food is presented. For a short time this established association is retained, but it gradually wanes away. In this experimental case the association was obviously a useless one; but similar associations of a useful kind are often established in the early life of animals, and they illustrate part of the meaning of our term "registration." Experience rivets (non-intelligent) associations between a certain sensory signal—a touch, a sound, an odour, a change of light and so on—and some useful action, such as opening the mouth, snapping, crouching, standing stock-still, or moving very rapidly. These linkages count for much in everyday life, when fumbling might often be fatal.

The next step is habit-forming, which means the linking of a chain of actions so that they form a sure and rapid sequence. We inadvertently lay our hand on a very hot surface, but we immediately jerk it off, without either thought or will, and in a much shorter time than it takes to say "reflex action," which is the technical name for what has happened. What is it that actually happens? (1) The ends of sensory nerve-fibres in our finger-tips are stimulated, and the thrill passes to the sensory nerve-cells in the ganglia on the dorsal roots of the spinal nerves. (2) The message travels to "adjustor" nerve-cells in the spinal cord. (3) Thence it is shunted to adjacent motor nerve-cells. (4) From these the commands pass to the muscles, the "effectors" of the movement. Thus there are (1) scout-cells (sensory neurons), (2) G.H.Q. cells (adjustor neurons), (3) executive officer cells (motor neurons), and (4) those carrying out orders (muscle-cells). The chain has four links, which may be represented by the letters S→A→M—E. Some of the linkages are inborn (as those of swallowing or sneezing), while others are individually acquired, as in a game of skill.

But in a *habit*, there is a *sequence* of these linkages : S→A→M→E leading to s→a→m→e, which in turn gives the cue to *s→a→m→e*; and habituation means that the sequence of different linkages has through practice become easy. This is a way of enregistering experience that counts for much in the dexterities of animals, such as that of the "Magnificent Spider" of Australia, which catches small moths by rapidly whirling a viscid droplet on the end of its silken thread ! But in a case like this it is difficult to believe that the spider is without some awareness of its useful dexterity.

There is thus a gradual inclined plane from the starfish "learning" to right itself up to the collie-dog learning to shepherd its sheep through difficult situations : and, as we pass from the lower to the higher, the organic memory comes to be more and more constantly accompanied by mental memory, which implies the retention and revival of images.

A common device for testing an animal's power of "learning" is to make a maze, a miniature of Hampton Court's, rewarding the creature when it gets quickly through without blundering. A docile rat will become in the course of a few days quite familiar with the maze, and will scamper through it. We do not know *how* it "learns" its lesson—which it can master even apart from sight and smell—but there is no doubt as to the registration. After an interval of several weeks without any maze-experience, a "clever" (well-trained) rat will run through the perplexing paths without a mistake. Marvellous as this is, it is far below the level of effort of the most intelligent mammals—the dog and horse, elephant and monkey. The school of comparative psychologists known as "extreme Behaviourists" seeks to reduce practically all that used to be called memory to the level of linked reflexes; but when one sees a dog set off by itself and journey some distance to a field where it was disappointed of a rabbit yesterday, it still seems to us good sense, *i.e.* good science, to say that the dog is somehow *remembering.* To test the well-known and probably authentic story of the tailor who suffered for pricking the elephant's trunk, a scientifically-disposed gentleman of leisure gave "My Lord" a sandwich with much cayenne pepper. After six weeks he revisited the elephant, who seemed to receive his courtesies without resentment. But just as the experimenter had made up his mind that the story of the tailor was untrue, he was deluged from head to foot with dirty water from the elephant's trunk. What word is there for this but memory?

Enough, then, to illustrate what is meant by individually enregistered experience, which we have deliberately kept apart from reflexes, tropisms, constitutional rhythms, and full instinctive capacities—all of them dependent, on their physiological side, on hereditary pre-arranged linkages between particular nerve-cells and particular muscle-cells. It is not denied, indeed, that while some forms of instinctive behaviour are exhibited in extraordinary perfection the very first time—a spider's prentice web is true to its species—there are others that are improved by repetition. But there is an undeniable difference between inborn skill and acquired dexterity. The difficult problem is whether individual registration of acquired dexterities can in any way affect, or find entailment in the racial inheritance.

Now to summarise. Looking back along the inclined plane of animal behaviour, we discern two main modes: (*a*) the expression of enregistered capacities for effective response, and (*b*) some initiative or fresh experimentation. On the one side of the plane or curve we rank simple reactions, simple reflexes, compound reflexes, tropisms, constitutional rhythms, simple instincts, chain instincts, and habituated intelligent behaviour. On the other side of the curve we rank simple tentatives, "trial and error" procedure, non-intelligent experiments, experiential and associative "learning," and intelligent behaviour. Each line might be drawn double, the convex side indicating physiological processes (biosis), the concave side indicating mental processes (psychosis). An exposition of this idea will be found in Thomson's *Biology of Birds* (1923).

CHAPTER IX

WHAT IS LIFE?

What is Life? The commonest answer to this question—which has perplexed the minds of men since we know not when—may well be—"I know, when you do not ask me!" But biologists and physicians have ever striven to get further than this; and hence have given various answers, until at length we have the Characteristics of the Living, as in Chapter I. Yet here, towards further questioning, let us start anew with something of historic retrospect.

Enough here to begin with that of Bichat—though obviously in principle as old as thought—"life is the sum of the functions which resist death." True, of course, so far as it goes; and only superficially contradictory to Claude Bernard's—"Life is Death"—since this was his epigrammatic summary of his deeper view of functions in terms of their physico-chemical changes, their metabolisms, and these necessarily with destructive changes (katabolisms), as well as constructive processes (anabolisms); so that it is even physiologically true that "in the midst of life, we are in death." Lewes—a serious thinker of Stuart Mill's time, and way, but with more of science—defined life as "a series of definite and successive changes, both of structure and composition, which take place within an individual without destroying its identity"; while a somewhat later writer of theological and idealistic standpoint describes life as "the invisible, individual, co-ordinating cause directing the forces involved in the production and activity of any organism possessing individuality." These two latter descriptions are still of interest, since not only illustrating contrasted standpoints of the last century, but as substantially expressing for it the "mechanistic" (and physico-chemical), and thus "materialistic" view-point, and the contrasted "vitalistic" doctrine of life in this historic controversy, not yet ended.

Note, however, that both types so far agree, in concentrating on life as of the organism, in itself: since omitting any reference to surrounding circumstances. But from the days of Lamarck to those of Comte—indeed, for that matter from Hippocrates—these, with other writers of their times, had seen the essential importance of not omitting the *milieu* of life; and Mr. Spencer did the great service, for English language and thought alike, of translating milieu as "environment"—a word since and increasingly familiar. Hence both organism and environment are kept in view in his definition of life, as "the definite combination of heterogeneous changes, both simultaneous and successive, in correspondence with external co-existences and sequences." So far well: for we must henceforth free ourselves from this frequent defect—even of the mechanistic tradition, let alone the vitalistic—of concentrating on their chosen aspect of the organism, thus too much thought of as standing by itself, and as if apart from the environment; though with complexities of this its whole functioning is concerned. In other words, we blame the vitalists for too habitually thinking and writing of "vital forces" yesterday and of "entelechy" or "*élan vital*" to-day, with inadequate grappling with the questions of how these may concretely deal with environmental conditions and events; yet as naturalists we cannot feel the prevalent insistence upon the essential physics and chemistry of protoplasm or cell, with all its undeniable interest, to be adequately satisfying either. It is encouraging to note recent books, like Dr. Haldane's—clearly re-expressing the conception of function in terms of organism and environment together; for though it would be indignantly denied, by vitalistic and mechanistic writers alike, that they could seriously think of respiration without both its organs and their atmosphere, and thus as functional interchange between these, we cannot but press them both towards a more consistent and thoroughgoing maintenance of this principle throughout their writings. The difficulty is that this interaction of life with its surroundings is so familiar in life and habit that it has long lacked more careful consideration by either school: so upon this view of life in its functioning let us now concentrate.

A Notation for the Life-Process.—We may take it now as accepted by all that life, as process, as relation, is twofold—of Environment in action upon organism, and of Organism upon environment. See now if we cannot clearly express this simple conception of life-process in that clearest of languages which gets below verbal languages altogether, the notations in which the mathematician thinks and writes; and these often as his equations, here fortunately of the very simplest. Represent Life as L, how write its equation? $L = x$, as the unknown, is what we begin with; but now to "solve" this x, interpret it as definitely as may be? For environment let us write E for its active aspect, and e for its passive aspect, when reacted on. Organism may similarly be written o when acted on, and O when active or reactive. Take function as f, in both cases.

The determination of life by circumstance, the action of Environment on organism, ($E \rightarrow f \rightarrow o$) may be briefly set down as *Efo*; and its converse and complement, the reaction of life upon circumstance, that of Organism on environment ($O \rightarrow f \rightarrow e$), may be written *Ofe*. Both these represent but half-processes: each statement—*Ofe* and *Efo*—is thus but a half-truth. In life they succeed each other; yet they keep together, and in mutual relation

—*ratio*. Thus our x of Life, confronted with this life-process, notated in its twofold aspect, becomes

$$L = x = Efo : Ofe.$$

Or, with ratio otherwise stated,

$$L = x = \frac{Efo}{Ofe}.$$

But on the whole the former will generally be found most convenient.

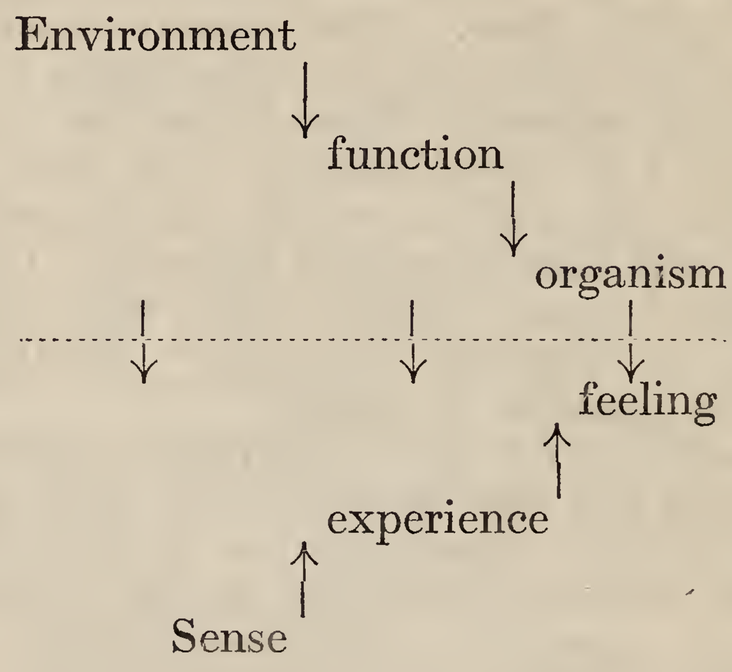
We know, and only too well by experience, that many are impatient of the simplest notations: yet if the reader will but look into this simple life-formula with patience, he will see in it that we are not claiming too much for it, as it opens to his mind's eye, as lucid, even luminous; as suggestive, even evocatory. For when we have in mind the magnitude of this problem of understanding life, not only organic, but human, and thus its importance for all that man and his thought have most valued throughout the ages, it is much to see, in *Efo*, the domination of life by circumstances; and, in *Ofe*, the domination by life of circumstances. For the first half-formula not only sums up—but thence, spell-wise, evokes and brings into view—the spectacle of life, as bowed before inexorable Fate, submissive to impassive Gods: the other shows Life overthrowing Titans, accomplishing heroic labours. Similarly in great world-religions, with their oft-contrasted heresies and sects: so too through the history of philosophies, with their many schools; ever the same ill-balanced claims, of Determinism on the one side, of Freedom on the other. And so even in our modern times, with their splintered contrasts; witness the confusion of their politics, the sterility of their economics—as for single example, yet in both of these increasingly potent—"the economic interpretation of history" so generally pushed to extremities of doctrine and action on one hand; and the converse over-insistence on purely idealistic and moral interpretation in university and church; hence powerless accordingly to react on minds of socialist and revolutionist, save indeed further to exasperate them, as seeming to them but "reactionary."

So in the world of leisure, with its "print-habit"; for here most seek the novel of circumstance, but some that of character. Many follow the games of chance, though some contest the championships of strength and skill: and the crowding spectators of the latter are thus mainly of the former type, whose life yet seeks vicariously for what it fails in.

In childhood, however, we read *Robinson Crusoe* and *Pilgrim's Progress* by turns: for though the hero of the first appears when sorely dominated by circumstances, he rises to the occasion, and thus soon dominates his isle: and though Christian sets out upon the ideal pilgrimage, he has no lack of amazing difficulties and glorious adventures on the way. But as we mature, we mostly settle down, even to fixity, with its insistence upon one habitual view, its under-valuation, even to forgetfulness, of the other. Thus educationists have tended to over-stress the importance of nurture, and eugenists those of nature. So too modern evolution-theorists have too much renewed this old quarrel in their particular terms, and hence disputed between "Luck or Cunning"—one insisting on "the All-sufficiency of Natural Selection," another on internal agencies of change.

Psychology in Life.—Differing psychological views are also present in all such discussions of life; consciously so to the vitalist, though often subconscious to the mechanist, save in opposition. Neither disputes, however, the obvious and increasing senses of the animal world, nor, in higher types at least, their manifestations of feeling; while their learning by experience is increasingly carried into experimental marvels. But sense deals primarily with the environment; feeling fundamentally permeates the organism, and this in relation to its essential life, thus from hunger to sex, from offspring to herd or grouping. And the association of experience with functioning in environment is again obvious, intricate and perplexing though it becomes, as, for instance, with the evolution of "instinct" and its applications.

The Life-process, on its (determinist) *Efo* side, and now viewed as organic and as psychological by turns, but best together, appears in summary thus—



Our " biology " and " psychology " are here seen linked together. But if so, their separation, in our customary way, does not really constitute them two separate sciences, properly so called; we see now that these are only our separate sides—convenient, and even necessary for analysis—of the simple old unitary way of studying and interpreting life as we see it, whether in watching the robins, or in choosing a horse. " Biologist " and " Psychologist," though alike starting from the old naturalists, by turns observant, and would-be interpretative, have arisen by their division of critical labours. So far well, but next not well; since becoming one-sided and thus often opponents, like the knights who quarrelled over the silver and golden sides of the same shield. But with the later progress of life-science they have each had to take note of the other's phenomenal viewpoint. So now their studies are becoming viewed anew, a good deal as in the old natural history way, though this more advanced, more critically treated. Thus, in fact, our for a time mutually exclusive studies are coming together again, as "Bio-psychology," and advancing in collaboration.

Yet their meeting is not on equal terms: for the more biologic mind—which cannot but retain the naïve attitude of the sciences of observation, which have developed apart from the discussions of philosophy—must here at once claim that the psychologic functionings, as above notated, are but the "epi-phenomena" of the organismal life; as Huxley, in his direct and outspoken way, long ago called them. Our psychology, so far, at any rate, is thus frankly "materialistic"; so that the psychologists of the older schools, despite this naturalistic psychology, see in it but a scanty concession, and that to veil a real aggression; hence naturally enough they are more displeased with us than ever. Moreover, younger and later bio-Psychologists have arisen, substantially acceptant of this epiphenomenal view; and—equipping themselves with instruments of measurement yet more subtle than those of the physiological laboratories which first trained them—they have measured not only sensibilities, but functionings, and traced the experience of these even into measuring fatigues and pains. So even for feeling: since what the most controlled human face may conceal, may be detected, as in the circulation by the plethysmograph. And next, beyond such experimental and physiological psychologists, we have to recognise a further group, increasingly working towards their forcibly-stated goal, of a comprehensive "Behaviour-psychology," and often with progress as little to be ignored as is that of the bio-chemists on their side, however the old vitalists in their day might oppose it with futile protest.

With Bio-psychology thus in the ascendant, the old psychology naturally seems to be sinking fast; and its disappearance, despite colours still flying, appears but a question of time, and that the life-expectancy of survivors. Undeniably, behaviourism demolishes more and more of the anthropomorphic interpretations of the old natural history: it is thus more than threatening even our good old dog-friend, with that renewal of Descartes' automaton view, which one of Huxley's "Lay Sermons" long ago so clearly recalled. Indeed, most seriously of all, this bio-psychologic automaton view is found increasingly applicable—and is thus vigorously applied—even to many of our human thinkings and doings; so the older psychology has again and again to give back, and surrender field after field of those it had so long held as secure.

At this rate, where is the traditional psychology, which holds by an inner life, to find any position it can really hold? As to human life, it can and does fall back upon its highest developments, and recalls to their would-be besiegers such frank admissions as those of Wallace, that he could see no way of evolutionary development for these—say of the mathematical faculty or the musical, let alone the philosophical and the religious. But the attack answers—granted, of course, for yesterday, and even to-day—but that does not affect our extending trenches, our deepening mines, for new attack to-morrow.

And, as consistent evolutionists—whatever our sympathies—must we not admit they must thus proceed? For otherwise, would not both antagonists have to agree that life, and with it our world-view, must be in dualism; whereas unity is not only the postulate of each science, but the united goal of all. Without this Master-Guest indeed, there could be no researches to speak of, in any field of science; for each and all of these has been, is, and must be, undertaken and prosecuted in the faith that, however strange, variable and perplexingly intricate may be the phenomena of its particular field, these notwithstanding are somehow orderly; as indeed becomes manifest when the discovery is reached. Hence since order, law, unity, thus appear in every field yet investigated—be it of form, of process, of succession, or of all together—who, and above all what man of science, can reasonably lose faith in an all-prevailing unity, "unseen, yet in unbroken line, through man and beast, through grain and grass"? In the full verse from which that line is taken, Emerson—our poet of Evolution before even Tennyson—broadly combines the contrasted perspectives of the two main schools of thought—which helps to explain why he has been too little read by either of them. But scientists shrink from poets, since they must creep far oftener than fly. So recall for a little our elder initiator of evolution doctrines, Lamarck. His view, of organic function making the organ by use-inheritance, was far too naïve, as Neo-Lamarckians freely admit: but they increasingly revive his next conception beyond this, one psychical in character, of inwardly felt need and urge, as "desire." Yet the child does not add to his stature by stretching his neck, however strong his wish; so why the giraffe either, with all his behaviour of hungry desire? The Darwinian explanation—that, given high-placed foliage, it will be the giraffes which happen to have varied towards longer necks, which can thereby best browse, survive and bear young, again thus variable, and again nature-selected—was thus far more obviously satisfying. Yet students of growth and development are bringing fresh points, of deeper view; and these—without, of course, excluding the scrutinies and tests of natural selection—bring into view an urge of life, in child's growth, and in giraffe's alike. Organic urge this is, of course: but the biologist, nowadays becoming bio-psychologist, is not entitled wholly to deny to the life-processes and activities of either creature some bio-psychologic aspect, but must indeed claim this, epiphenomenal though for him it still seems. Indeed, since psychical characters are inherited, and thus through the fertilised ovum, what biologist can now be materialistic enough to shrink from Haeckel's thorough-going monism, thus granting the cell a psychic aspect as well as an organic? Moreover, are not all the preceding views facilitated, and not a little, by the modern "psychology of the Subconscious"? If then "*Élan Vital*" be thus psychically interpreted, and even "Entelechy" viewed as its most comprehensive aspect, these terms become less alarming to consistent evolutionists than they at first seemed.

It is, of course, still obvious that all this is far from satisfying, or even congenial, to our older school of psychologists, or to those of kindred associations; though they must admit it is something for biologists to be recognising psychology at all.

Look once more at our life-formula, not simply Efo, but Efo : Ofe. These obviously go on repeating, and with change also: since action on environment does so far change it, and it may be notably; as, for instance, when we stay too long in a closed room; or, for better instance, if we make plant-life purify its air for us. Thus our formula becomes Efo : Ofe $\longrightarrow$ E′fo : O′fe. Environment and Organism may thus change together, though the Organism more obviously. They may thus even come to fit together closely, as in so many adaptations. Have we not here indeed, not only the beginning of a notation for modifications by environment, but one worth trying to extend and apply to adaptations?

But without pursuing side-applications we return to the main values of this life-formula, as two. First, that it comprehends and correlates the environment and the organism, too long and still too commonly torn asunder, too long divided between the physicist and the morphologist, each thus static, hence necrographic. Secondly, it enables us to keep clearly in view both the organic and the psychic aspects of their interaction—too much separated, as "body" and "mind"—say rather, since now accurately, as "corpse" and "ghost"; and these as the prey of necrologist and phantomologist respectively.

The Life-Process More Clearly Stated.—Leaving now these aside together, return to our biology proper, with its study of life's organic and psychic aspects associated, as what we may now call Bio-psychosis. In ordinary life we act, we do things, thus modifying our environment; indeed that is our main life-functioning, our day's work, our life-work in sum. Our at first subconscious, then dim, vague, confused, and slowly dawning, "*desire*" comes at length to clearness and decision as Will. In the measure that we have come to "work with a will," we escape from mere toil, mere slavery, to freedom; we have got beyond mere external determinism, of however initially pressing, exacting, even threatening circumstance, be this of natural environment or of social bondage. This aspect of our life's urge, towards victory over circumstance, can no longer be called mere Bio-psychosis: it is the very converse; in a word, it is Psycho-biosis. Our modification of our environment, be it to great victory or but as stout endeavour, is now no longer merely epi-phenomenal. It is Psycho-epi-phenomenal, since such life-functioning is no longer merely imposed from without, but its emergent response from within.

But, it must fairly be asked, what of every reflex action? Is it not the stimulus from without ($\underrightarrow{\text{Efo}}$), that evokes ($\underrightarrow{\text{Ofe}}$), the response? That stimulus does stimulate, who will deny? Yet what better test of rank, and rise, both in individual development, and in the scale of being also, than the quality and measure of this response? Is not here the essential process of evolution?

Life is in these days so vividly condensed into games (whence their interest and popularity, primarily for childhood, for youth, but found well worth continuing into age as well) that we may well typify stimulus as bowling, response as batting, and note how both have evolved together. We see that while the great bowler (here known as Environment) may and does knock out (Natural Selection) the weaker batsmen (organisms), it is still the guiding eye and ruling brain, served by trained and powerful muscle, of the best of these batting organisms that make their goodly score out of the difficult bowling, and thus establish the main glory of such players and their game.

Thus then we learn by living, complexer environment going with completer sense, complexer organismal development in association with intenser and more varied feeling, while the correspondingly complexer interaction of all these deepens experience, enriches memory, awakens intelligence. These subjective factors also react upon one another, sense flowing into experience, this into feeling, and, of course, reversely too: indeed all with further correlations too complex for present limits.

Our outline-beginnings of a notation for the further study of biology and psychology together may thus be carried a step further, indeed in indefinite series (and prolonged either way)—$\downarrow\frac{\text{Efo}}{\mathit{Efo}} \rightarrow \uparrow\frac{\text{Ofe}}{\mathit{Ofe}} \rightarrow \downarrow\frac{\text{E}'\text{fo}}{\mathit{E'fo}} \rightarrow \uparrow\frac{\text{O}'\text{fe}'}{\mathit{O'fe'}}$.

The italicised denominators of the "relations" indicate the psychical aspects; and our view is thus of no mere parallelism, but of interaction, and of an interaction that is developmental, even evolutionary.

The Notation of Social Life.—Environment, Function, Organism, albeit the three essentials of the chord of life, are still terms somewhat abstract: at any rate too general; as even the experienced biologist soon comes to feel when he tries to work out their interactions, and still more to define these in notation. Whereas when we turn to the highest species, Man himself, and employ his old human terms for these three essentials —Place, Work, People—or (say) Family, Folk, etc.—there is an immediate gain in familiarity, concreteness and vividness, and consequently an easier comprehensibility of their interactions. Thus, too, with man himself, biology began, as we have seen above, and so indeed for each and all of its subsciences. In modern teaching of biology (though against this the human anatomist has long protested) it has become customary, and with advantages of simplicity, convenience, etc., to begin with simple forms, and proceed upwards; so that human studies appear at the culmination of our preliminary ones, and thus also as evolutionary climax. But here, with our present insistence upon the importance of a clear general conception of Life, the converse and original order reappears, justified in reason, in investigating and learning. We may thus for a little consider our human life and experience first, and this not simply in the interest of facilitating our understanding of human and social studies, but of our biology itself. Is it said, by any naturalist teacher devoted to the type-system, chosen in ascending order, and ending before coming to man—This method, though natural enough when naturalists were mostly doctors, is surely now out of date! But the reply is as easy: Too much so, doubtless; but who last used it?—and this for the crowning interest and glory of our science, breaking new paths, even for other sciences, with their triumphant contribution to the doctrine of Evolution—who but Darwin and Wallace? And both alike were led to discern Natural Selection because they had found it lacking in Malthus on "Population"; as also to emphasise the struggle for existence, since this was suggested to them by its extreme manifestations in the practice and economic theory of our industrial and commercial age, and also in the wars which have preceded and accompanied its rise. So manifest is this essential account of these biological initiators, as based on economist precursors, that a notable American historian of economics (and one not in any ignorance of Darwin's biological significance; indeed himself originally a skilled stock-breeder) describes Darwin as "the last of the great British economists."

So if the human and even social approach was good enough for Darwin and Wallace, and so fruitful for biology, it may well be good for us and our science to try the same again. What indeed if the diminution of extensive grasp and comprehensive furtherance of our science which has been too often apparent since Darwin's day be not solely the consequence of the resulting (and needed) intensification of all its specialisms, but also in consequence of its specialists cloistering themselves in their laboratories and museums, apart from their fellow-evolutionists in the human and social fields? May it not be time to say: Since Darwin took a horse from these, and found it Pegasus, may we not look over the hedge again?

We are thus seeking not only the logic of life, but something of its practical conduct (*i.e.* its ethic) also; and with rewards in widening consciousness, deepening sympathies also, with the whole world of life around us, human and simpler together. We may thus look anew over the fields of life and its evolution, and review their sub-sciences, but now in yet clearer grouping, fuller understanding also, than in our biological terms (Efo) alone. For with *Environment* as Place, we are entering on the full study of Geography, and this in widening concreteness of outlook, beyond our studies and homes. We see—*i.e.* observe, scrutinise, even "survey"—our own human hive, our city, town or village, and find this rich in even a biological suggestiveness, only in these times beginning to be appreciated; we survey too our immediate region, and thus begin to understand those beyond, even to their making up of the wide world, with its varied human and organic life. Our Environment has thus been extending: our own Place is seen to be more significant than before.

So next as "Function" humanises and realises into Work, such work as our place provides, even compels (Efo), or admits of within our powers (Ofe). Moreover, here we are in the true laboratory of Economics; and we see how and why so many economists —of any and every school—fall short and fail, if they have not adequately come to grips with their would-be science by passing through work-experience; but have been content to listen to the bargainings of the market. So too when our chosen type-organisms are human Folk: since we here gain no less illumination from anthropology, with its folk-ways, folk-lore, and so on. We even see fresh light on all these three main sub-sciences—Geography (Place), Economics (Work), and Anthropology (Folk)—when we realise their correlation, and escape from their long-persisting detachment—their dis-specialism, as separate societies, institutes, museums, libraries, university departments, or miscellaneous reading—into the elements of a unifying chord of life, fundamental henceforth to a yet more unifying science—Sociology.

Our first outline of life's synthesis, helpful for all the four living sub-sciences of Biology, as Efo : Ofe, can now be thoroughly parallelised with the like for Sociology as Pwf : Fwp, as we have just seen that arise, from the unified sub-sciences of Place, Work and Folk. And though these have been long in coming to recognise their place within its larger fold, this cannot be much longer delayed. For this assures them an increased vitality and productivity; and not only for their respective problems and tasks, but far more as they become collectively incorporated, and indeed clearly and solidly interwoven, as the fundamental and initial web of sociology.

Organism and Society.—There is, however, a yet more general question, which no student, whether of general biology or of social science, can long escape facing, since each must ask—What of the essential relation between the two? While "Organism" seems naturally given as the subject of biology, and "Society" as obviously given for sociology, the questions of comparing Organism with Society—and of course conversely, Society with Organism—cannot be escaped on either side, and indeed seem highly promising ones. Hence biology has no small literature of this kind, since it cannot but arise in principle as soon as our survey of the animal kingdom rises from the protozoon to the sponge, from hydra to hydroid, or from the solitary sea-anemone to the vast composite of the coral; or as we pass from the individualistic gall-fly to the socialistic bees, and thence also to the ants, with their yet more marvellous and varied towns. On this line of biological study, and towards social grade-comparison, the first monograph was indeed that of Espinas, afterwards an economist of note; but Perrier and later zoologists have continued it too. It is, however, on the side of sociology, for obvious reasons, that the comparison of

Society with Organism has been most laboured; as notably by Herbert Spencer, and also by later writers, up to to-day.

Yet all these comparisons have after all borne too little fruit for either science: and if we ask—Why?—What has gone wrong?—the notations $\frac{\text{Efo : Ofe}}{\text{Pwf : Fwp}}$ answer plainly. For here the essential comparison is seen; no longer merely, or even mainly, of the Organism with the folk, the people, the Society, but as that of their respective life-processes. For organic life and social life agree in principle, in their necessary and constant interaction with environment; yet with innumerable differences as well as resemblances between the three essential factors of each; not only therefore between organism and society, but between organic functioning and economic, as also between the relatively simple biological environment, with the far more complex social one. How this notation not only serves to extricate us from inadequate (or often forced) comparisons, but next may be applied and developed—with substantial clearing up, for the social field especially, but for those of biology too; and thence even with better comparisons accordingly—is thus not only a long story, but manifold; and hence too elaborate for treatment within these limits.

Summary.—Our answer to the question What is life? has been neither that of the mechanist nor of the vitalist, but has utilised, even combined, the characteristic doctrine of each. For with $\downarrow\frac{\text{Efo}}{Efo}$ on the one side we associate $\uparrow\frac{\text{Ofe}}{Ofe}$ on the other; and similarly for human life as social, $\downarrow\frac{\text{Pwf}}{Pwf} : \uparrow\frac{\text{Fwp}}{Fwp}$. That is, we do justice to environmental impressions and experiences on one side of our notation, yet to organismal and social impulse and expression on the other. We see, then, in the process and progress of life, the alternation of stimulus and response, of passivities and activities, in unending yet varying rhythm; with the latter on the whole as increasingly potent and thus directive, even *telic*. In short, life's oscillations, between Bio-psychosis and Psycho-biosis, show coadjustment, and even of the former by and through the latter. Both external determinisms and internal selections thus have their influence throughout life, yet towards predominance of the latter—and this as the varying measure of evolutionary rise.

This conception of life, in process and in change, will also be seen to distinguish mere environmental modifications from the uprush and outcome of the mutations proper, with their changes of life's rhythm. First clearly, of course, in human life, and in their social fields, where they are each so plainly manifested—yet why only there?

Here then is a theory of life—one inviting, even challenging, further discussion and fuller enquiry, and these in the world of nature, in the zoological and botanic garden, and in the experimental work; as well as in self and others, and in university and city.

At any rate—be this doctrine approved or not—how better can we conclude our preceding outlines of the progress of life-studies in their various fields, than by a theory of life which touches all of them, and raises questionings throughout their ever-increasing evolutionary range?

ENVOI

The Applications of Biology (Biotechnics).—Into the vast fields of Applied Biology it is here beyond our limits to enter. Yet though pure science is here our problem, it is Life-science; and thus it is legitimate to point out that its clearer charting, and in relations as full as may be, is helpful, towards clearer applications as well. As a first outline towards this required clearness, our second diagram may readily be turned over, upon an opposite page. Thus we have a complete mirror-reversal of our schema of the sciences; and with like spaces; but now for charting the main arts of life in their orderly relations to each other, and, of course, to the sciences as well. Yet though we commonly speak of "applied" sciences as if they came second, the reverse is largely true—for none will deny how much the arts have been originative to the sciences, nor how suggestive still.

The associated principle of organised action must here be noted. On the whole, in science, we use the ascending order (mathematical, physical, biological, social); and thence we have come to consider the subjective sciences proper (logic, æsthetics, psychology, ethics) in their prime associations with the objective ones. But upon the side of action, we may—and indeed do—best begin upon the highest level, the practically social. We thence descend; and, moreover, with each and all lines of concrete action organised; yet each and all now impelled and guided from their subjective side. Hence true Politics is Etho-Politics; and thus true Biotechnics has as far as may be—and thus above all in human life and education—to be also Psycho-technics. Industry (Technics) has to be "a good job"; and it thus becomes Eutechnics, as were the crafts as well as arts of old. And for Metrics, we must clearly know what we are measuring for:—hence Thematimetrics—for its logical, and indeed whole subjective, guidance—and power.

Thought and Action, Action and Thought, are thus capable of fertile and even lucid integration in the mind; and, hard though it must ever be to realise this in practice, such Orchestration of Life is clearly conceivable. It is even in detail defensible upon our charting, and is thus more plain before us.

As practical minds then, is it not time to have done with our after-War despairings and thus again look forward into the coming years—for which already, beyond the ageing forces of reaction and revolution, the Practical Idealists—thus Ideopraxists—are gathering, especially among youth? For these, all the past, with its great initiatives, should be at best but as of precursors, towards renewed initiatives. And these have now to be increasingly co-ordinated, towards the guidance of Human and Organic Evolution. Evolution-lore is thus seen to be not merely a deciphering of origins, but also a discernment of paths.

The way is difficult and long: no chartings can ever fully suffice; yet life's insurgence is ever seeking and finding its way. *Vivendo discimus.*

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